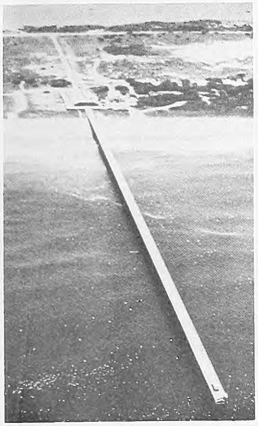
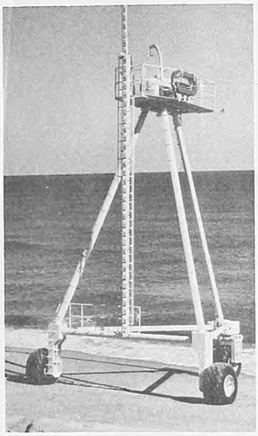
US Army Corps of Engineers





TECHNICAL REPORT CERC-90-13

ANNUAL DATA SUMMARY FOR 1988 CERC FIELD RESEARCH FACILITY

Volume I

MAIN TEXT AND APPENDIXES A AND B

by

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Coastal Engineering Research Center

DEPARTMENT OF THE ARMY
Waterways Experiment Station, Corps of Engineers
3909 Halls Ferry Road, Vicksburg, Mississippi 39180-6199

WATERWAYS EXPERIMENT STATION · US ARMY ENGINEER ·

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Final Report

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This report provides basic data and summaries for the measurements made during 1988 at the US Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center's (CERC's) Field Research Facility (FRF) in Duck, NC. The report includes comparisons of the present year's data with cumulative statistics from 1980 to the present.

Summarized in this report are meteorological and oceanographic data, monthly bathymetric survey results, samples of quarterly aerial photography, and descriptions of 16 storms that occurred during the year. The year was highlighted by a severe storm in April that destroyed several oceanfront cottages. Waves with 5-m significant height were measured 6 km from shore.

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Meteorologic research--statistics (LC)
Oceanographic research--statistics (LC)
Oceanographic research stations--North Carolina--Duck (LC)
Water waves--statistics (LC)

19. ABSTRACT (Continued).

This report is tenth in a series of annual summaries of data collected at the FRF that began with Miscellaneous Report CERC-82-16, which summarizes data collected during 1977-1979. These reports are available from the WES Technical Report Distribution Section of the Information Technology Laboratory, Vicksburg, MS.

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PREFACE

This report is the tenth in a series of annual data summaries authorized by Headquarters, US Army Corps of Engineers (HQUSACE), under Civil Works Research Work Unit 32525, Field Research Facility Analysis, Coastal Flooding Program. Funds were provided through the US Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center (CERC), under the program management of Dr. C. Linwood Vincent, CERC. Mr. John H. Lockhart, Jr., was HQUSACE Technical Monitor.

The data for the report were collected and analyzed at CERC's Field Research Facility (FRF) in Duck, NC. The report was prepared by Mr. Michael W. Leffler, Computer Programmer Analyst, FRF, under the direct supervision of Mr. William A. Birkemeier, Chief, FRF Group, Engineering Development Division (EDD), and Mr. Thomas W. Richardson, Chief, EDD; and under the general supervision of Dr. James R. Houston and Mr. Charles C. Calhoun, Jr., Chief and Assistant Chief, CERC, respectively. Mr. Kent K. Hathaway, Oceanographer, FRF, assisted with instrumentation; and Mr. Brian L. Scarborough, Amphibious Vehicle Operator, FRF, assisted with data collection. Messrs. Herman C. Miller, Clifford F. Baron, John B. Strider, Jr., James E. Martin, and Mark A. McConathy and Mses. Deborah R. Heibel and Wendy L. Smith assisted with data analysis at the FRF. The National Oceanic and Atmospheric Administration/National Ocean Service maintained the tide gage and provided statistics for summarization.

Commander and Director of WES during the publication of this report was COL Larry B. Fulton, EN. Dr. Robert W. Whalin was Technical Director.

CONTENTS

* A limited number of copies of Appendixes C-E (Volume II) were published under separate cover. Copies are available from National Technical Information Service, 5285 Port Royal Road, Springfield, VA 22161.

ANNUAL DATA SUMMARY FOR 1988
CERC FIELD RESEARCH FACILITY

PART I: INTRODUCTION

Background

1. The US Army Engineer Waterways Experiment Station (WES), Coastal Engineering Research Center's (CERC's) Field Research Facility (FRF), located on 0.7 km^2 at Duck, NC (Figure 1), consists of a 561-m-long research pier and accompanying office and field support buildings. The FRF is located near the middle of Currituck Spit along a 100-km unbroken stretch of shoreline extending south of Rudee Inlet, VA, to Oregon Inlet, NC. The FRF is bordered by the Atlantic Ocean to the east and Currituck Sound to the west. The Facility is designed to (a) provide a rigid platform from which waves, currents, water levels, and bottom elevations can be measured, especially during severe storms; (b) provide CERC with field experience and data to complement laboratory and analytical studies and numerical models; (c) provide a manned field facility for testing new instrumentation; and (d) serve as a permanent field base of operations for physical and biological studies of the site and adjacent region.

2. The research pier is a reinforced concrete structure supported on 0.9-m-diam steel piles spaced 12.2 m apart along the pier's length and 4.6 m apart across the width. The piles are embedded approximately 20 m below the ocean bottom. The pier deck is 6.1 m wide and extends from behind the duneline to about the 6-m water depth contour at a height of 7.8 m above the National Geodetic Vertical Datum (NGVD). The pilings are protected against sand abrasion by concrete erosion collars and against corrosion by a cathodic system.

3. An FRF Measurements and Analysis Program has been established to collect basic oceanographic and meteorological data at the site, reduce and analyze these data, and publish the results.

4. This report, which summarizes data for 1988, continues a series of reports begun in 1977.

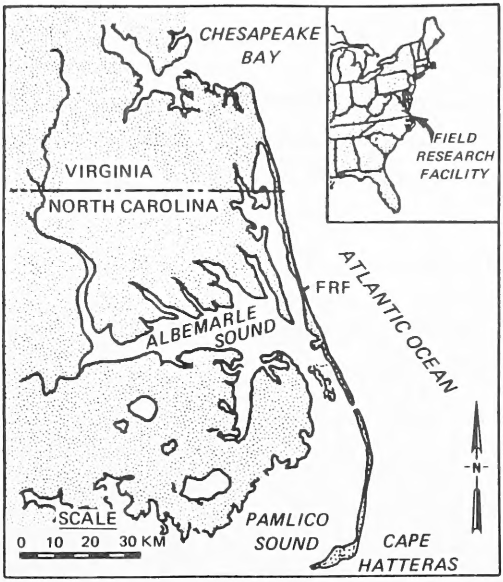

Figure 1. FRF location map

Organization of Report

5. This report is organized into nine parts and five appendixes. Part I is an introduction; Parts II through VIII discuss the various data collected during the year; and Part IX describes the storms that occurred. Appendix A presents the bathymetric surveys, Appendix B summarizes deep-water wave statistics, and Appendixes C through E (published under separate cover as Volume II) contain summary statistics for other gages.

6. In each part of this report, the respective instruments used for monitoring the meteorological or oceanographic conditions are briefly described along with data collection and analysis procedures and data results. The instruments were interfaced with the primary data acquisition system, a Digital Equipment Corporation (Maynard, MA) VAX-11/750 minicomputer located in the FRF laboratory building. More detailed explanations of the design and the operation of the instruments may be found in Miller (1980). Readers' comments on the format and usefulness of the data presented are encouraged.

Availability of Data

7. Table 1 summarizes the available data. In addition to the wave data summaries in the main text, more extensive summaries for each of the wave gages are provided in Appendixes B through E.

Table 1

1988 Data Availability

	Gage	Jan					Feb				Mar				Apr					May				Jun				Jul					Aug				Sep				Oct					Nov				Dec			
	ID	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4	1	2	3	4	5	1	2	3	4	1	2	3	4
Weather																																																					
Anemometer	632	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Atmospheric Pres.	616	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Air Temperature	624	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*
Precipitation	604	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Waves																																																					
Offshore Waverider	630	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	*	*	*	*	/	*	*	*	*	/	*	*	*	*	*	/	*	*	*	*	/	*	*	*	*	*	/	/	/	*	/	*	*	*	*	/
Pressure Gage	111	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	*	*	*	*	/	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Pier End	625	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	-	-	-	-
Pier Nearshore	645	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	/	*	*	*	*	/	/	*	*	*	*	*	/	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*
Currents																																																					
Pier End		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Pier Nearshore		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Beach		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Pier End Tide Gage		*	*	*	*	*	*	*	*	/	/	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Water Characteristics																																																					
Temperature		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Visibility		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Density		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	/	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Bathymetric Surveys							*							*			*							*				*										*										*		*		*	
Photography																																																					
Beach		*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*	*
Aerial		*																*																*					*			*											

Notes: * Full week of data obtained.
/ Less than 7 days of data obtained.
- No data obtained.

8. The annual data summary herein summarizes daily observations by month and year to provide basic data for analysis by users. Daily measurements and observations have already been reported in a series of monthly

Preliminary Data Summaries (Field Research Facility 1988). If individual data for the present year are needed, the user can obtain detailed information (as well as the monthly and previous annual reports) from the following address:

USAE Waterways Experiment Station
Coastal Engineering Research Center
Field Research Facility
SR Box 271
Kitty Hawk, NC 27949-9440

Although the data collected at the FRF are designed primarily to support ongoing CERC research, use of the data by others is encouraged. The WES/CERC Coastal Engineering Information and Analysis Center (CEIAC) is responsible for storing and disseminating most of the data collected at the FRF. All data requests should be in writing and addressed to:

Commander and Director
US Army Engineer Waterways Experiment Station
ATTN: Coastal Engineering Information Analysis Center
3909 Halls Ferry Road
Vicksburg, MS 39180-6199

Tidal data other than the summaries in this report can be obtained directly from the following address:

National Oceanic and Atmospheric Administration
National Ocean Service
ATTN: Tide Analysis Branch
Rockville, MD 20852

A complete explanation of the exact data desired for specific dates and times will expedite filling any request; an explanation of how the data will be used will help CEIAC or the National Oceanic and Atmospheric Administration (NOAA)/National Ocean Service (NOS) determine if other relevant data are available. For information regarding the availability of data for all years, contact CEIAC at (601) 634-2012. Costs for collecting, copying, and mailing will be borne by the requester.

PART II: METEOROLOGY

9. This section summarizes the meteorological measurements made during the current year and in combination with all previous years. Meteorological measurements during storms are given in Part IX.

10. Mean air temperature, atmospheric pressure, and wind speed and direction were computed for each data file which consisted of data sampled two times per second for 34 min every 6 hr beginning at or about 0100, 0700, 1300, and 1900 eastern standard time (EST); these hours correspond to the time that the National Weather Service (NWS) creates daily synoptic weather maps. During storms, data recordings were made more frequently. The data are summarized in Table 2.

Table 2

Meteorological Statistics

	Mean Air Temperature deg C		Mean Atmospheric Pres. mb		Precipitation, mm				Wind Resultants			
					1988	1978-1988			1988		1980-1988	
Month	1988	1983-1988	1988	1983-1988	Total	Mean	Maxima	Minima	Speed m/sec	Direction deg	Speed m/sec	Direction deg
Jan	3.9	5.0	1024.2	1017.8	124	100	180	44	2.6	349	2.6	339
Feb	6.1	6.0	1018.8	1017.3	86	72	86	20	1.2	313	1.8	350
Mar	9.9	9.1	1019.1	1016.2	37	79	168	35	0.2	27	1.4	358
Apr	13.6	13.5	1010.8	1013.2	100	95	182	0	1.4	354	0.4	319
May	17.9	18.8	1014.8	1016.2	49	64	239	20	1.5	64	0.4	173
Jun	22.2	23.2	1014.7	1015.5	118	80	130	27	0.5	246	1.0	199
Jul	25.8	26.0	1017.8	1016.5	60	81	200	19	3.0	208	1.7	215
Aug	25.4	26.0	1015.2	1016.5	121	105	221	30	2.0	176	0.5	98
Sep	21.3	22.2	1016.9	1018.0	35	72	160	5	3.0	25	1.9	36
Oct	15.1	17.4	1017.1	1019.8	69	64	143	17	2.3	352	2.5	27
Nov	13.9	13.3	1016.1	1018.6	120	93	145	26	0.6	331	1.9	357
Dec	6.4	8.2	1020.0	1019.8	16	62	131	4	2.2	301	2.1	335
Average	15.1	15.7	1017.2	1017.2	78	80			0.7	335	0.9	357
Total					935	967						

Air Temperature

11. The FRF enjoys a typical marine climate which moderates the temperature extremes of both summer and winter.

Measurement instruments

12. A Yellow Springs Instrument Company, Inc. (YSI) (Yellow Springs, OH) electronic temperature probe with analog output interfaced to the FRF's computer was operated beside the NWS's meteorological instrument shelter located 43 m behind the dune (Figure 2). To ensure proper temperature readings, the probe was installed 3 m above ground inside a "coolie hat" to shade it from direct sun yet provide proper ventilation.

Results

13. Daily and average air temperature values are tabulated in Table 2 and shown in Figure 3.

Atmospheric Pressure

Measurement instruments

14. Electronic atmospheric pressure sensor. Atmospheric pressure was measured with a YSI electronic sensor with analog output located in the laboratory building at 9 m above NGVD. Data were recorded on the FRF computer. Data from this gage were compared with those from an NWS aneroid barometer to ensure proper operation.

15. Microbarograph. A Weathertronics, Incorporated (Sacramento, CA) recording aneroid sensor (microbarograph) located in the laboratory building also was used to continuously record atmospheric pressure variation.

16. The microbarograph was compared daily with the NWS aneroid barometer, and adjustments were made as necessary. Maintenance of the microbarograph consisted of inking the pen, changing the chart paper, and winding the clock every 7 days. During the summer, a meteorologist from the NWS checked and verified the operation of the barometer.

17. The microbarograph was read and inspected daily using the following procedure:

a. The pen was zeroed (where applicable).

b. The chart time was checked and corrected, if necessary.

c. Daily reading was marked on the chart for reference.

d. The starting and ending chart times were recorded, as necessary.

e. New charts were installed when needed.

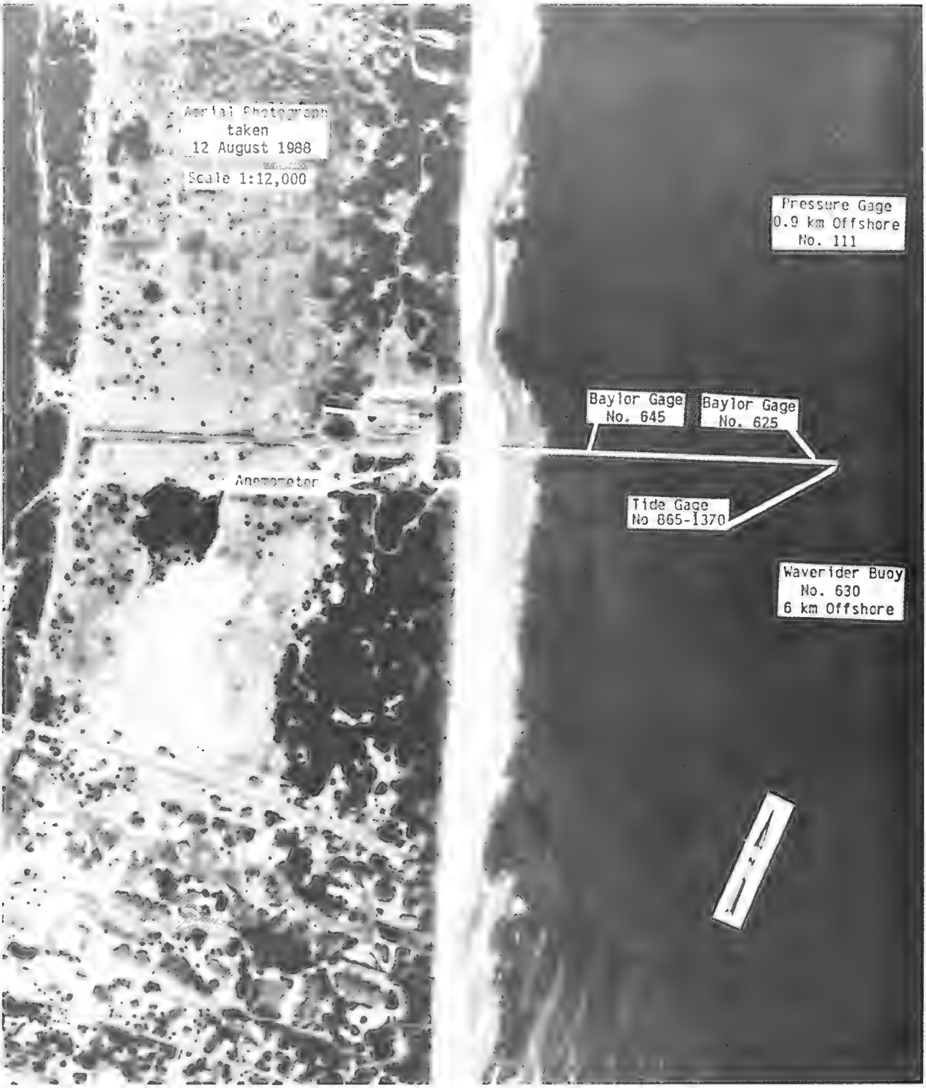

Figure 2. FRF gage locations

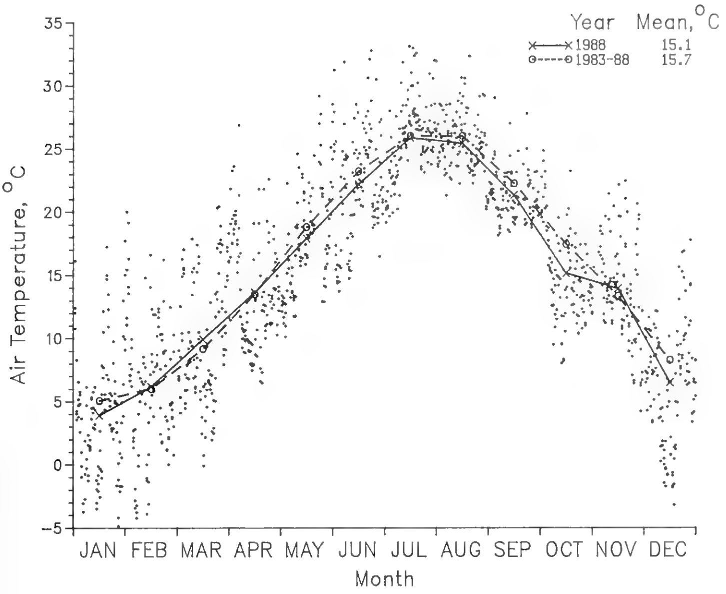

Figure 3. Daily air temperature values with monthly means

Results

18. Daily and average atmospheric pressure values are presented in Figure 4, and summary statistics are presented in Table 2.

Precipitation

19. Precipitation is generally well distributed throughout the year. Precipitation from midlatitude cyclones (northeasters) predominates in the winter, whereas local convection (thunderstorms) accounts for most of the summer rainfall.

Measurement instruments

20. Electronic rain gage. A Belfort Instrument Company (Baltimore, MD) 30-cm weighing rain gage, located near the instrument shelter 47 m behind the dune, measured daily precipitation. According to the manufacturer, the

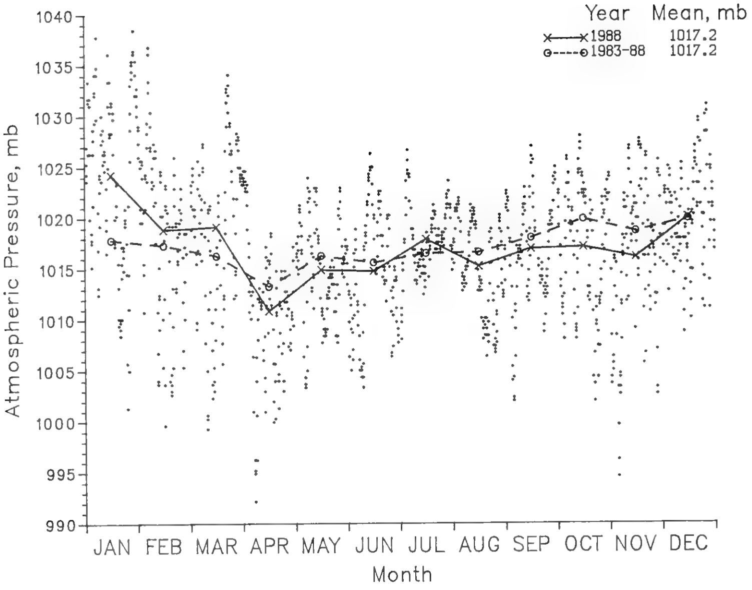

Figure 4. Daily barometric pressure values with monthly means

instrument's accuracy was 0.5 percent for precipitation amounts less than 15 cm and 1.0 percent for amounts greater than 15 cm.

21. The rain gage was inspected daily, and the analog chart recorder was maintained by procedures similar to those for the microbarograph.

22. Plastic rain gage. An Edwards Manufacturing Company (Alberta Lea, MN) True Check 15-cm-capacity clear plastic rain gage with a 0.025-cm resolution was used to monitor the performance of the weighing rain gage. This gage, located near the weighing gage, was compared daily; and very few discrepancies were identified during the year.

Results

23. Daily and monthly average precipitation values are shown in Figure 5. Statistics of total precipitation for each month during this year and average totals for all years combined are presented in Table 2.

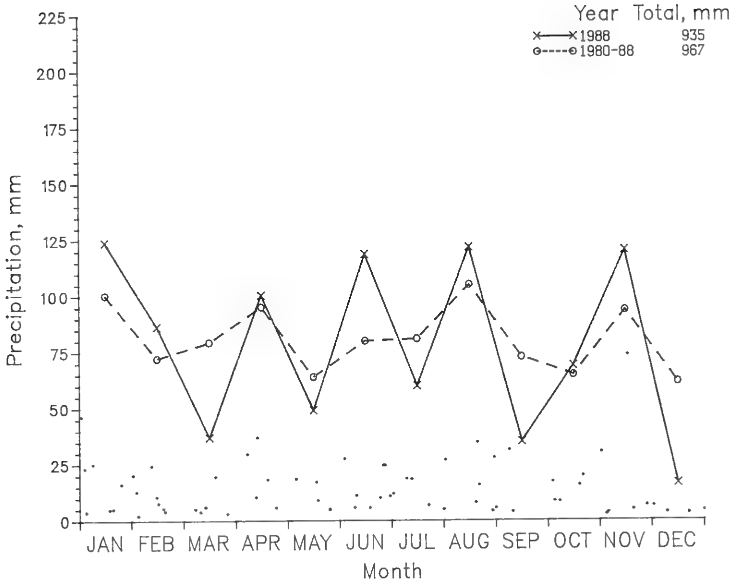

Figure 5. Daily precipitation values with monthly totals

Wind Speed and Direction

24. Winds at the FRF are dominated by tropical maritime air masses which create low to moderate, warm southern breezes; arctic and polar air masses which produce cold winds from northerly directions; and smaller scale cyclonic, low pressure systems, which originate either in the tropics (and move north along the coast) or on land (and move eastward offshore). The dominant wind direction changes with season, being generally from northern directions in the fall and winter and from southern directions in the spring and summer. It is common for fall and winter storms (northeasters) to produce winds with average speeds in excess of 15 m/sec.

Measurement instrument

25. Winds were measured on top of the laboratory building at an elevation of 19.1 m (Figure 2) using a Weather Measure Corporation (Sacramento, CA) Skyvane Model W102P anemometer. Wind speed and direction data were

collected on the FRF computer as well as on a strip-chart recorder. The anemometer manufacturer specifies an accuracy of ± 0.45 m/sec below 13 m/sec and 3 percent at speeds above 13 m/sec, with a threshold of 0.9 m/sec. Wind direction accuracy is ± 2 deg with a resolution of less than 1 deg. The anemometer is calibrated annually at the National Bureau of Standards in Gaithersburg, MD, and is within the manufacturer's specifications.

Results

26. Annual and monthly joint probability distributions of wind speed versus direction were computed. Winds speeds were resolved into 3-m/sec intervals, whereas the directions were at 22.5-deg intervals (i.e. 16-point compass direction specifications). These distributions are presented as wind "roses," such that the length of the petal represents the frequency of occurrence of wind blowing from the specified direction, and the width of the petal is indicative of the speed. Resultant directions and speeds were also determined by vector averaging the data (see Table 2). Wind statistics are presented in Figures 6, 7, and 8.

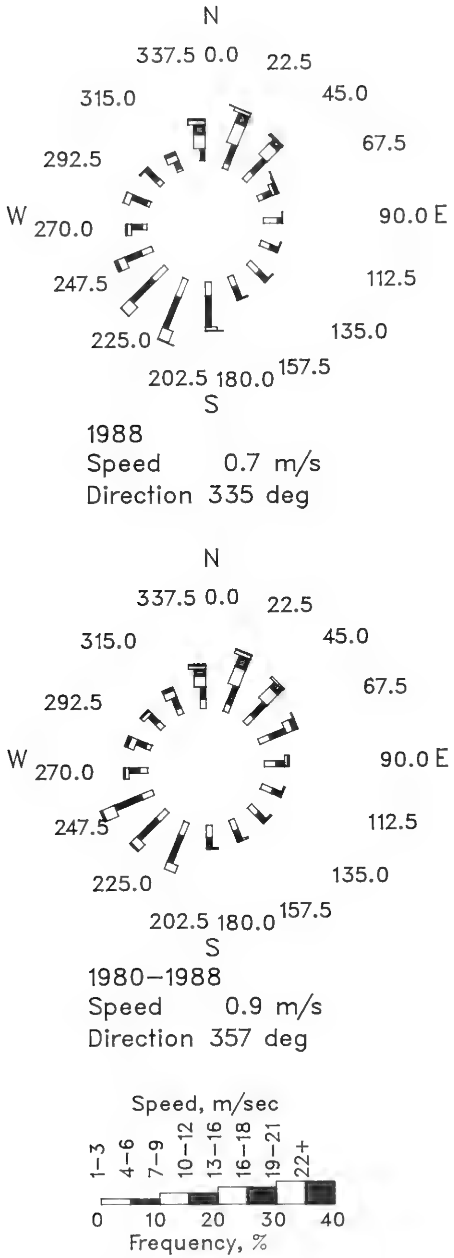

Figure 6. Annual wind roses

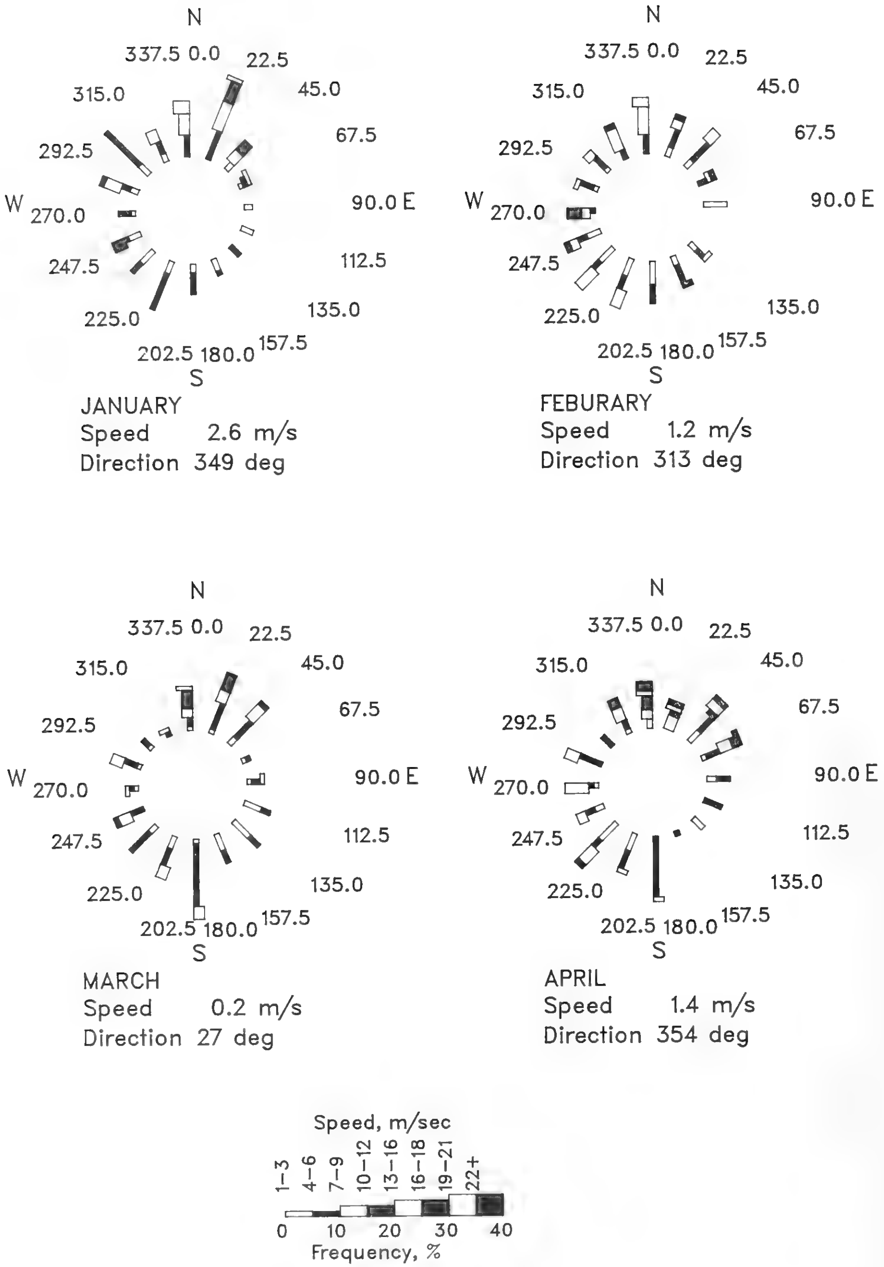

Figure 7. Monthly wind roses for 1988
(Sheet 1 of 3)

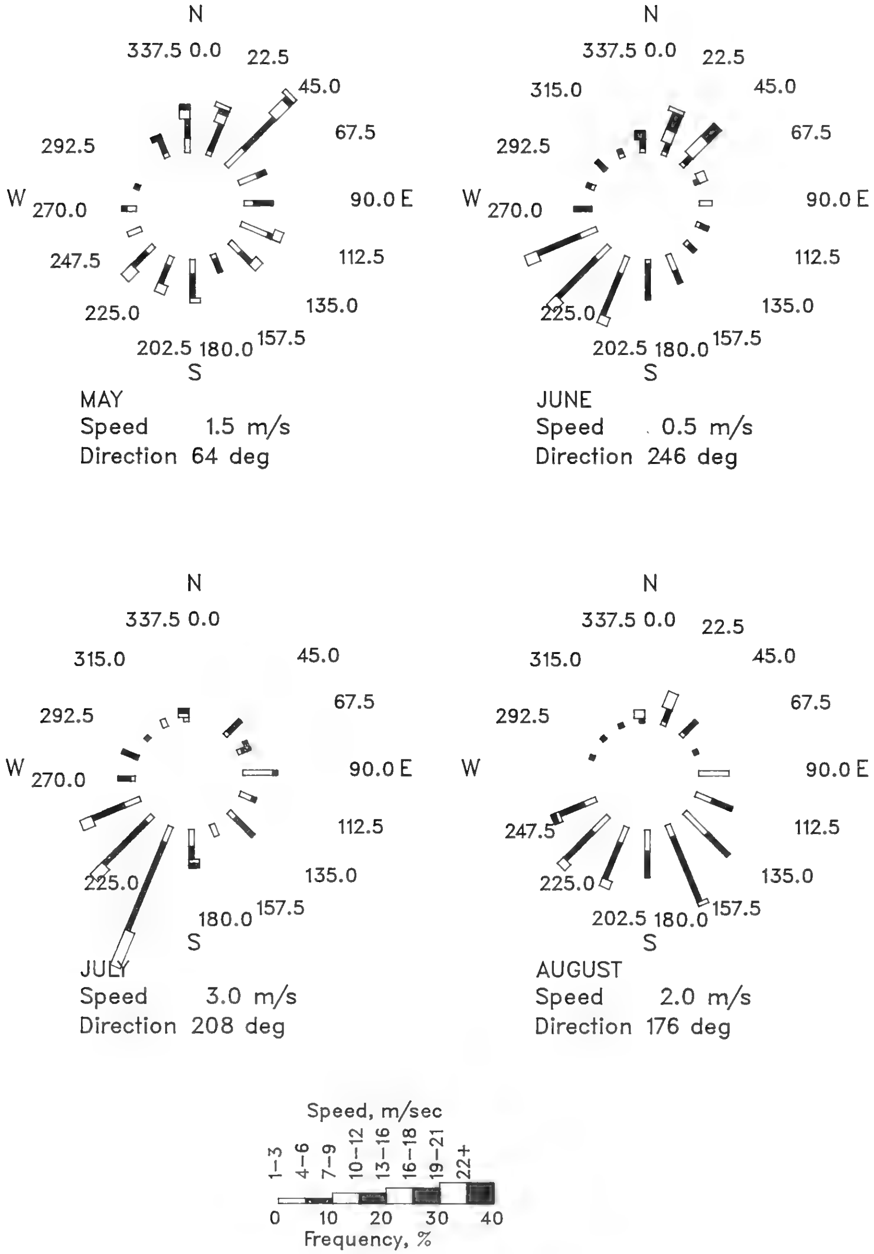

Figure 7. (Sheet 2 of 3)

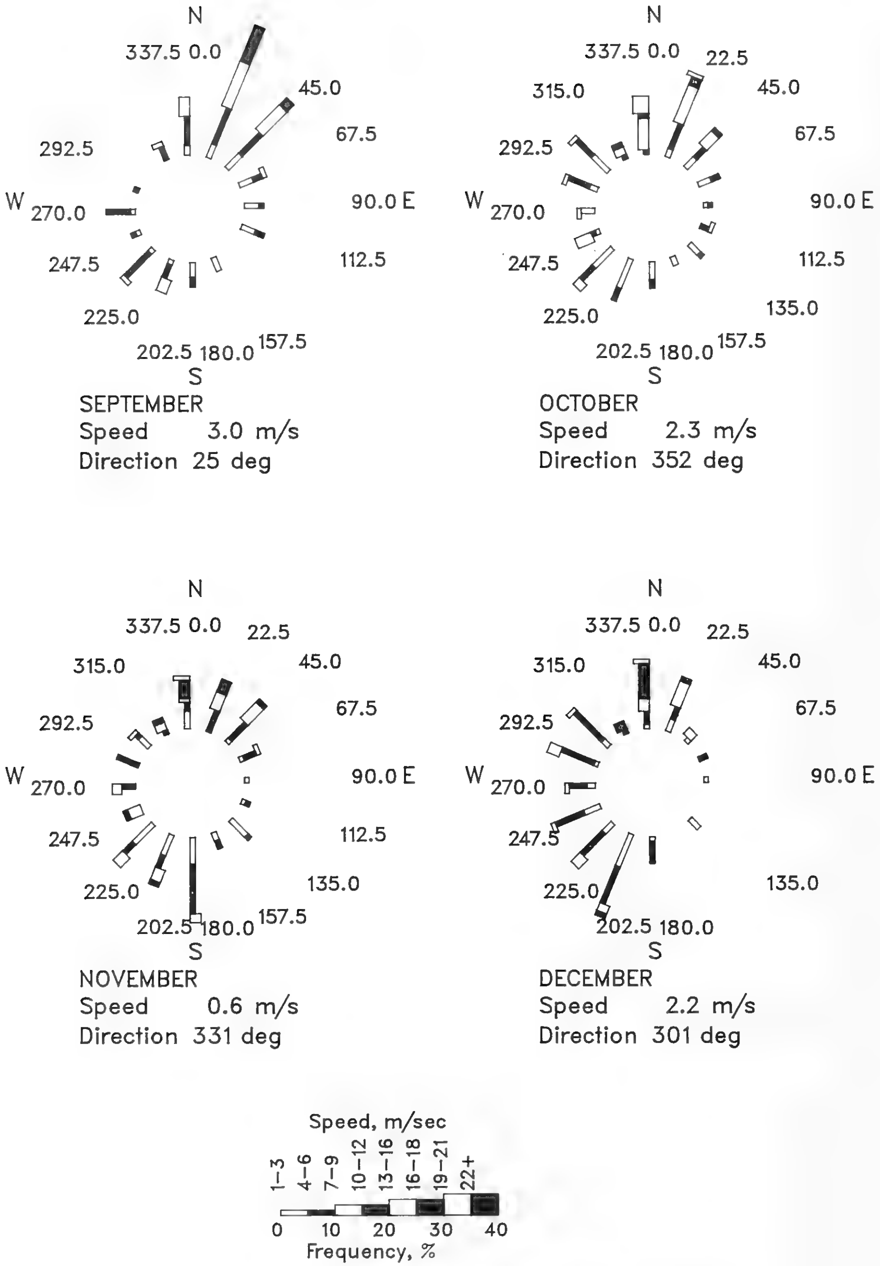

Figure 7. (Sheet 3 of 3)

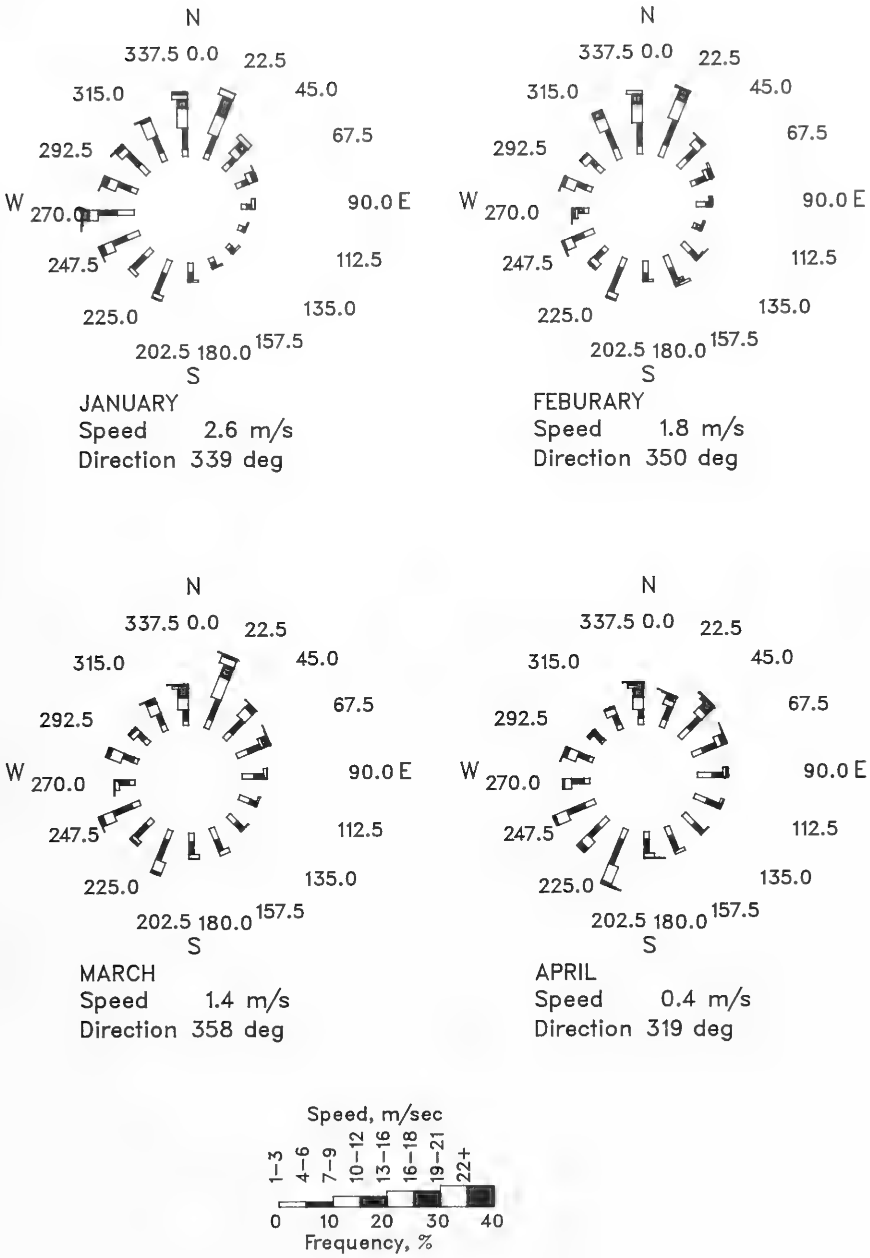

Figure 8. Monthly wind roses for 1980 through 1988 (Sheet 1 of 3)

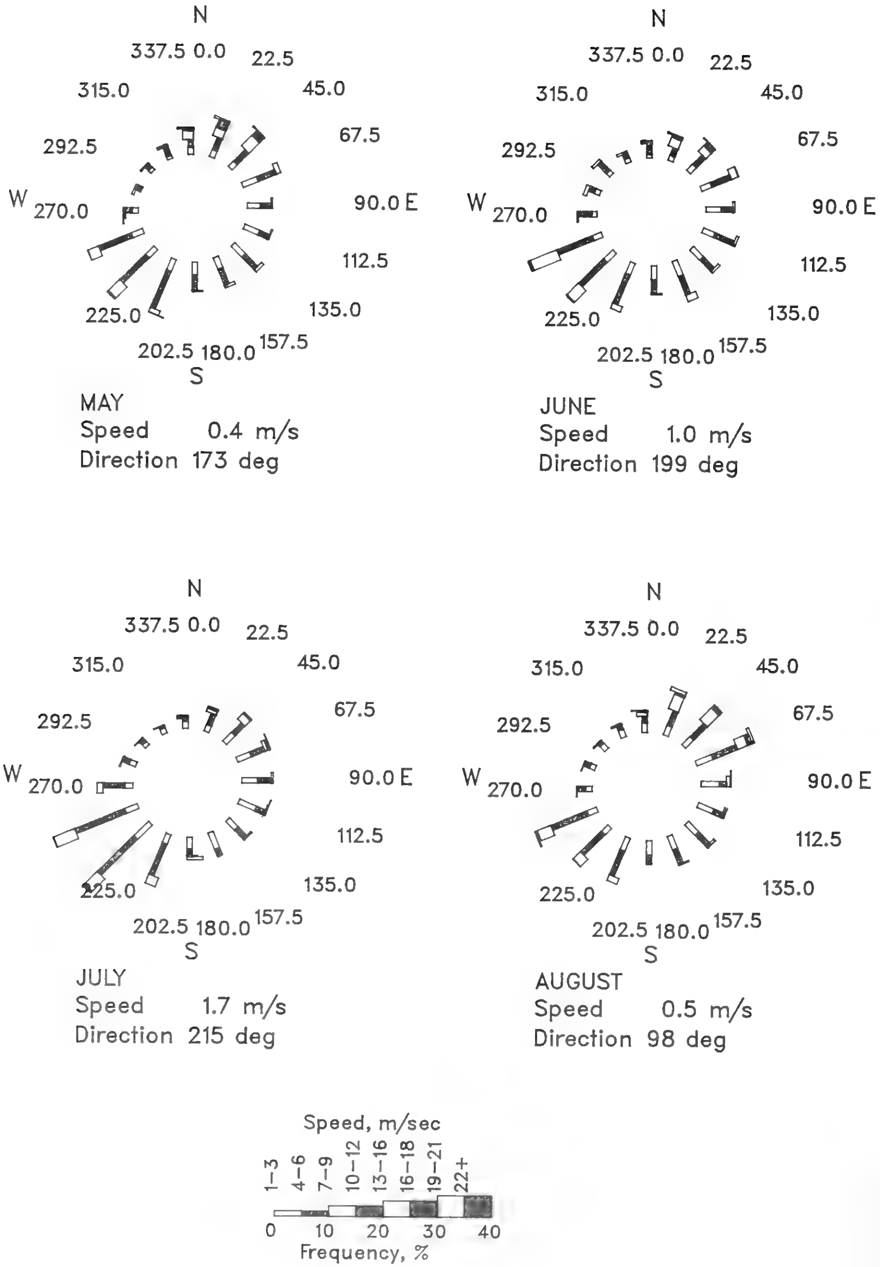

Figure 8. (Sheet 2 of 3)

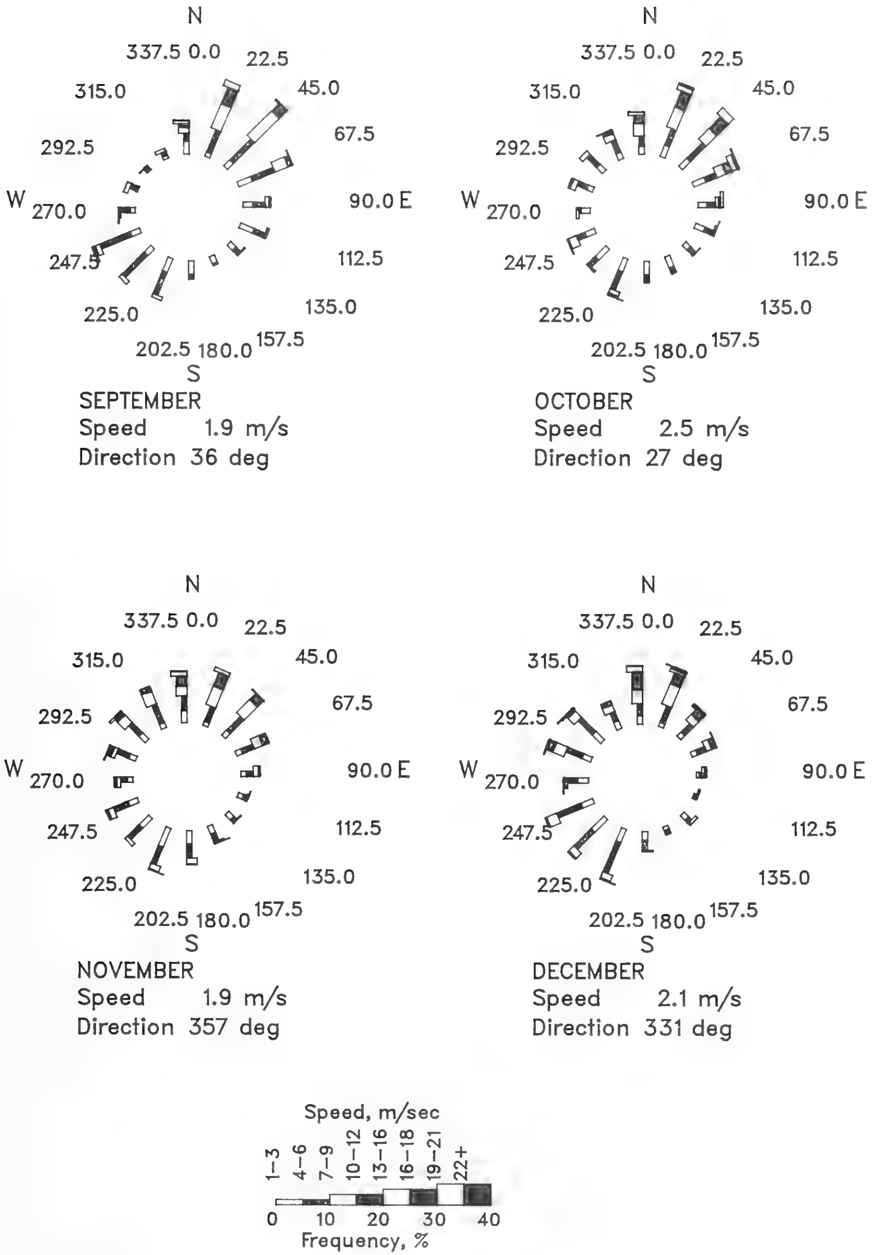

Figure 8. (Sheet 3 of 3)

PART III: WAVES

27. This section presents summaries of the wave data. A discussion of individual major storms is given in Part IX and contains additional wave data for times when wave heights exceeded 2 m at the seaward end of the FRF pier. Appendixes B through E provide more extensive data summaries for each gage, including height and period distributions, wave direction distributions, persistence tables, and spectra during storms.

28. Wave directions (similar to wind directions) at the FRF are seasonally distributed. Waves approach most frequently from north of the pier in the fall and winter and south of the pier in the summer, with the exception of storm waves which approach twice as frequently from north of the pier. Annually, waves are approximately evenly distributed between north and south (resultant wave direction being almost shore-normal).

Measurement Instruments

29. The wave gages included two wave staff gages (Gages 645 and 625), one buoy (Gage 630), and one pressure (Gage 111) as shown in Figure 2 and located as follows:

Gage Type/Number	Distance Offshore from Baseline	Water Depth m	Operational Period
Continuous wire (645)	238 m	3.5	11/84-12/88
Continuous wire (625)	579 m	8	11/78-12/88
Accelerometer buoy (630)	6 km	18	11/78-12/88
Pressure gage (111)	1 km	9	09/86-12/88

Staff gages

30. Two Baylor Company (Houston, TX) parallel cable inductance wave gages (Gage 645 at sta 7+80 and Gage 625 at sta 19+00 (Figure 2)) were mounted on the FRF pier. Rugged and reliable, these gages require little maintenance except to keep tension on the cables and to remove any material which may cause an electrical short between them. They were calibrated prior to installation by creating an electrical short between the two cables at known distances along the cable and recording the voltage output. Electronic signal conditioning amplifiers are used to ensure that the output signals from the gages are within a 0- to 5-V range. Manufacturer-stated gage accuracy is about 1.0 percent, with a 0.1-percent full-scale resolution; full scale is 14 m for Gage 625 and 8.2 m for Gage 645. These gages are susceptible to

lightning damage, but protective measures have been taken to minimize such occurrences. A more complete description of the gages' operational characteristics was given by Grogg (1986).

Buoy gage

31. One Datawell Laboratory for Instrumentation (Haarlem, The Netherlands) Waverider buoy gage (Gage 630) measures the vertical acceleration produced by the passage of a wave. The acceleration signal is double-integrated to produce a displacement signal which is transmitted by radio to an onshore receiver. The manufacturer stated that wave amplitudes are correct to within 3 percent of their actual value for wave frequencies between 0.065 and 0.500 Hz (corresponding 15- to 2-sec wave periods). The manufacturer also specified that the error gradually increased to 10 percent for wave periods in excess of 20 sec. The results in this report were not corrected for the manufacturer's specified amplitude errors. However, the buoy was calibrated semiannually to ensure that it was within the manufacturer's specification.

Pressure gage

32. One Senso-Metrics, Incorporated (Simi Valley, CA), pressure transduction gage (Gage 111) installed near the ocean bottom measures the pressure changes produced by the passage of waves creating an output signal which is linear and proportional to pressure when operated within its design limits. Predeployment and postdeployment precision calibrations are performed at the FRF using a static deadweight tester. The sensor's range is 0 to 25 psi (equivalent to 0- to 17-m seawater) above atmospheric pressure with a manufacturer-stated accuracy of ±0.25 percent. Copper scouring pads are installed at the sensor's diaphragm to reduce biological fouling, and the system is periodically cleaned by divers.

Digital Data Analysis and Summarization

33. The data were collected, analyzed, and stored on magnetic tape using the FRF's VAX computer. Data sets were normally collected every 6 hr. During storms, the collection was at 3-hr intervals. For each gage a data set consisted of 4 contiguous records of 4,096 points recorded at 0.5 Hz (approximately 34-min long), for a total of 2 hr and 16 min. Analysis was performed on individual 34-min records.

34. The analysis program computes the first moment (mean) and the

second moment about the mean (variance) and then edits the data by checking for "jumps," "spikes," and points exceeding the voltage limit of the gage. A jump is defined as a data value greater than five standard deviations from the previous data value, whereas a spike is a data value more than five standard deviations from the mean. If less than five consecutive jumps or spikes are found, the program linearly interpolates between acceptable data and replaces the erroneous data values. The editing stops if the program finds more than five consecutive jumps or spikes or more than a total of 100 bad points or the variance of the voltage is below 1×10^{-5} squared volts. The statistics and diagnostics from the analysis are saved.

35. Sea surface energy spectra are computed from the edited time series. Spectral estimates are computed from smaller data segments obtained by dividing the 4,096-point record into several 512-point segments. The estimates are then ensemble-averaged to produce a more accurate spectrum. These data segments are overlapped by 50 percent (known as the Welch (1967) method) and have been shown to produce improved statistical properties than from nonoverlapped segments. The mean and linear trends are removed from each segment prior to spectral analysis. To reduce sidelobe leakage in the spectral estimates, a data window was applied. The first and last 10 percent of data points was multiplied by a cosine bell (Bingham, Godfrey, and Tukey 1967). Spectra were computed from each segment with a discreet Fast Fourier Transform and then ensemble-averaged. Sea surface spectra from subsurface pressure gages were obtained by applying the linear wave theory transfer function.

36. Unless otherwise stated, wave height in this report refers to the energy-based parameter H_{mo} defined as four times the zeroth moment wave height of the estimated sea surface spectrum (i.e., four times the square root of the variance) computed from the spectrum passband. Energy computations from the spectra are limited to a passband between 0.05 and 0.50 Hz for surface gages and between 0.05 Hz and a high frequency cutoff for subsurface gages. This high frequency limit is imposed to eliminate aliased energy and noise measurements from biasing the computation of H_{mo} and is defined as the frequency where the linear theory transfer function is less than 0.1 (spectral values are multiplied by 100 or more). Smoother and more statistically significant spectral estimates are obtained by band-averaging contiguous spectral components (three components are averaged per band producing a

frequency band width of 0.0117 Hz).

37. Wave period T_p is defined as the period associated with the maximum energy band in the spectrum which is computed using a 3-point running average band on the spectrum. The peak period is reported as the reciprocal of the center frequency (i.e., $T_p = 1/\text{frequency}$) of the spectral band with the highest energy. A detailed description of the analysis techniques is presented in a report by Andrews (1987).*

Results

38. The wave conditions for the year are shown in Figure 9. For all four gages, the distributions of wave height for the current year and all years combined are presented in Figures 10 and 11, respectively. Distributions of wave period are presented in Figure 12.

39. Multiple year comparisons of data for Gage 111 actually incorporate data for 1985 and 1986 from Gage 640, a discontinued Waverider buoy previously located at the approximate depth and distance offshore as Gage 111 and data for 1987 from Gage 141, located 30 m south of Gage 111.

40. Refraction, bottom friction, and wave breaking contribute to the observed differences in height and period. During the most severe storms when the wave heights exceed 3 m at the seaward end of the pier, the surf zone (wave breaking) has been observed to extend past the end of the pier and occasionally 1 km offshore. This occurrence is a major reason for the differences in the distributions between Gage 630 and the inshore gages. The wave height statistics for the staff gage (Gage 645), located at the landward end of the pier, were considerably lower than those for the other gages. In all but the calmest conditions, this gage is within the breaker zone. Consequently, these statistics represent a lower energy wave climate.

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* M. E. Andrews. 1987. "Standard Wave Data Analysis Procedures for Coastal Engineering Applications," unpublished report prepared for the US Army Engineer Waterways Experiment Station, Vicksburg, MS.

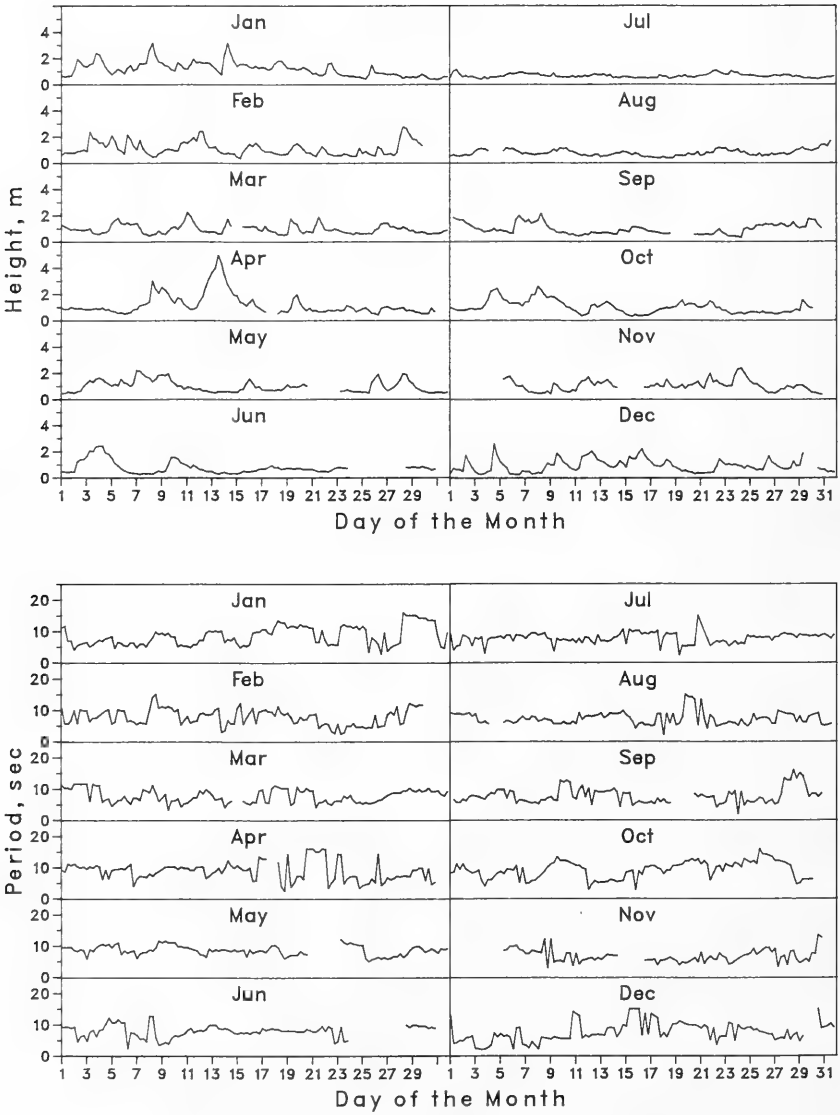


Figure 9. Time-histories of wave height and period for Gage 630

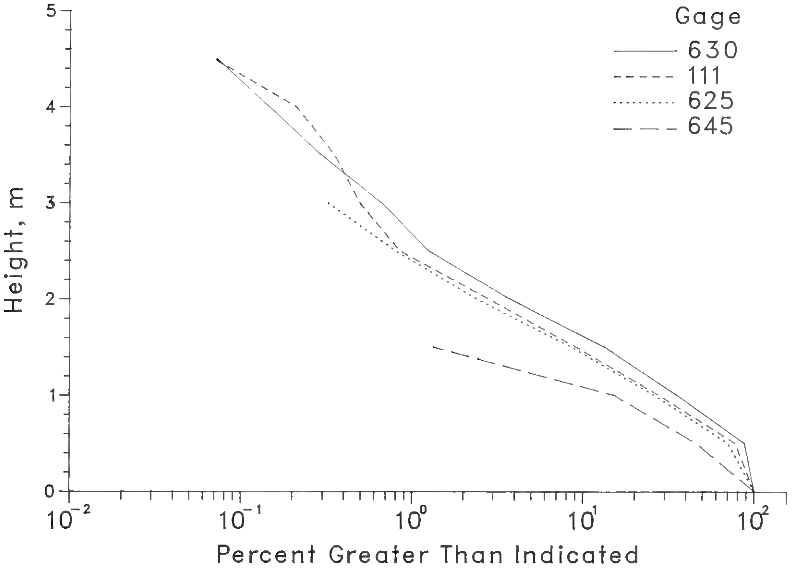


Figure 10. 1988 annual wave height distributions

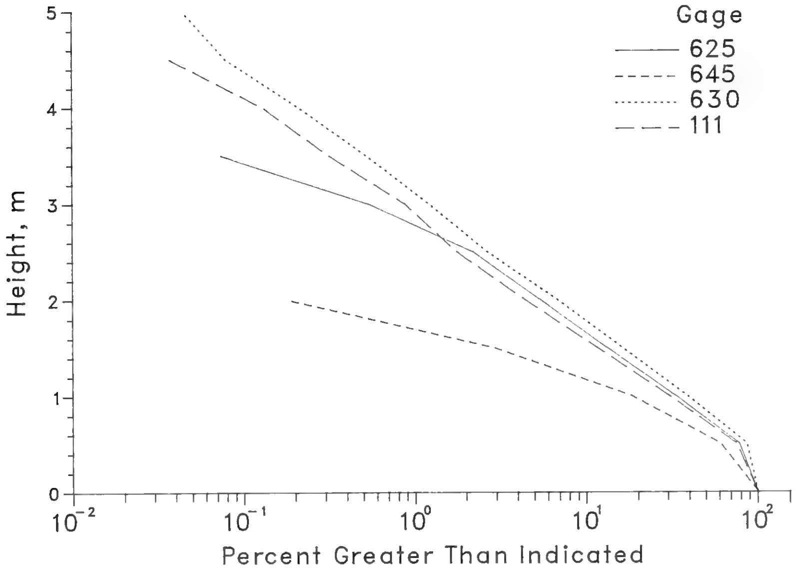


Figure 11. Annual distribution of wave heights for 1980 through 1988

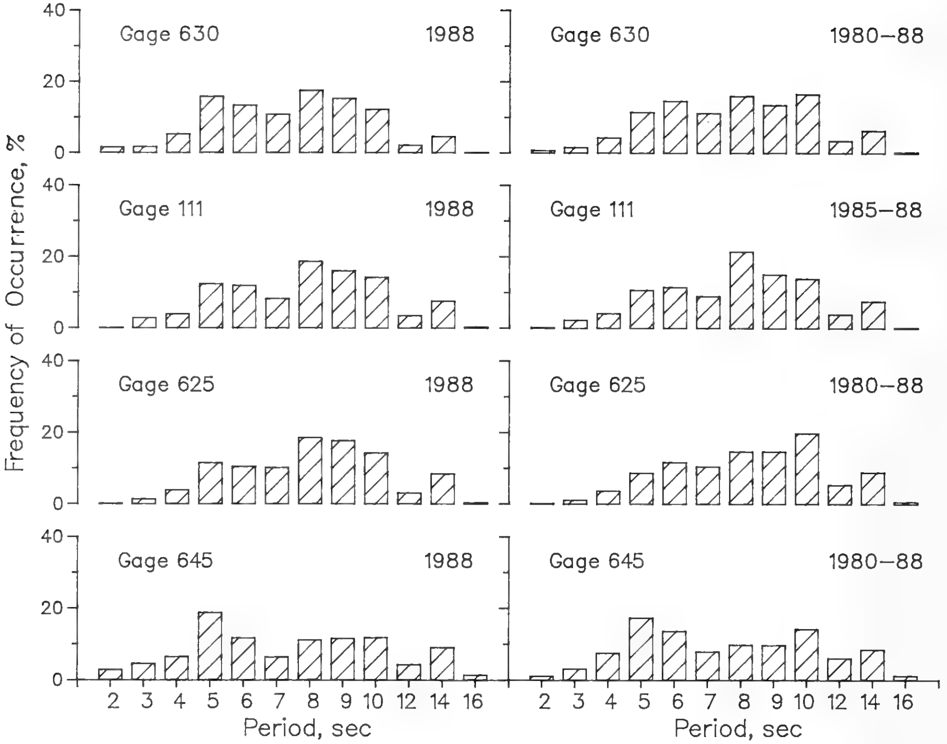


Figure 12. Annual wave period distributions for all gages

41. Summary wave statistics for the current year and all years combined are presented for Gage 630 in Table 3.

Table 3

Wave Statistics for Gage 630

	1988							1980-1988						
	Height				Period			Height				Period		
Month	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.
Jan	1.2	0.6	3.1	8	8.5	3.1	124	1.2	0.7	4.5	1983	8.0	2.8	950
Feb	1.1	0.6	2.7	28	7.8	2.6	116	1.2	0.7	5.1	1987	8.5	2.6	905
Mar	1.0	0.4	2.2	11	7.8	2.2	121	1.2	0.7	4.7	1983	8.6	2.7	998
Apr	1.3	0.9	5.2	13	8.9	3.1	116	1.1	0.7	5.2	1988	8.7	2.8	975
May	1.0	0.5	2.2	7	8.6	1.6	111	0.9	0.5	3.3	1986	8.1	2.3	983
Jun	0.8	0.5	2.4	4	8.0	2.0	101	0.8	0.4	2.4	1988	7.7	2.2	927
Jul	0.7	0.2	1.1	1	7.9	1.7	121	0.7	0.3	2.1	1985	8.1	2.5	948
Aug	0.8	0.3	1.6	31	7.4	2.1	119	0.8	0.5	3.6	1981	7.9	2.4	949
Sep	1.0	0.5	2.1	8	7.8	2.5	111	1.0	0.6	6.1	1985	8.5	2.6	960
Oct	1.0	0.5	2.6	8	9.3	2.7	108	1.2	0.7	4.3	1982	8.7	2.8	1039
Nov	1.1	0.5	2.4	24	6.8	2.1	94	1.2	0.7	4.1	1981	7.9	2.8	861
Dec	1.0	0.5	2.6	4	7.6	3.2	118	1.1	0.7	5.6	1980	8.3	3.0	887
Annual	1.0	0.6	5.2	Apr	8.0	2.6	1360	1.0	0.6	6.1	Sep 1985	8.3	2.6	11382

42. Annual joint distributions of wave height versus wave period for Gage 630 are presented for 1988 in Table 4, and for all years combined in Table 5. Similar distributions for the other gages are included in Appendixes B-E.

43. Annual distributions of wave directions (relative to True North) based on daily observations of direction at the seaward end of the pier and height from Gage 625 (or Gage 111 when data for Gage 625 were unavailable) are shown in Figure 13. Monthly wave "roses" for 1988 and all years combined are presented in Figures 14 and 15, respectively.

Table 4

Annual Joint Distribution of H_{mo} versus T_p for Gage 630

Annual 1988
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	88	22	22	103	22	96	301	301	103	44	103	.	1205
0.50 - 0.99	66	147	301	662	551	610	1051	904	662	118	191	.	5263
1.00 - 1.49	.	.	184	515	456	221	206	199	272	29	118	.	2200
1.50 - 1.99	.	.	22	265	199	74	110	74	154	22	37	.	957
2.00 - 2.49	.	.	.	29	81	44	51	15	22	.	7	.	249
2.50 - 2.99	.	.	.	7	22	7	.	15	.	.	7	.	58
3.00 - 3.49	.	.	.	.	.	22	7	7	.	.	.	.	36
3.50 - 3.99	.	.	.	.	.	.	15	.	.	.	.	.	15
4.00 - 4.49	.	.	.	.	.	.	7	.	.	.	.	.	7
4.50 - 4.99	.	.	.	.	.	.	.	7	.	.	.	.	7
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	154	169	529	1581	1331	1074	1748	1522	1213	213	463	0	

Table 5

Annual Joint Distribution of H_{mo} versus T_p for Gage 630 (All Years)

Annual 1980-1988
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	28	18	28	62	94	115	328	281	200	76	134	4	1368
0.50 - 0.99	39	128	254	499	572	515	860	717	812	151	213	15	4775
1.00 - 1.49	.	10	134	402	451	264	246	200	360	39	132	4	2242
1.50 - 1.99	.	.	13	156	256	109	79	70	139	35	77	4	938
2.00 - 2.49	.	.	2	26	78	74	49	41	70	29	41	2	412
2.50 - 2.99	.	.	.	1	9	32	17	16	38	11	23	.	147
3.00 - 3.49	.	.	.	.	1	9	15	14	17	4	9	.	69
3.50 - 3.99	.	.	.	.	.	1	5	7	10	4	4	.	31
4.00 - 4.49	.	.	.	.	.	.	2	2	7	1	2	.	14
4.50 - 4.99	.	.	.	.	.	.	.	1	3	.	.	.	4
5.00 - Greater	.	.	.	.	.	.	1	.	.	2	1	.	4
Total	67	156	431	1146	1461	1119	1602	1349	1656	352	636	29	

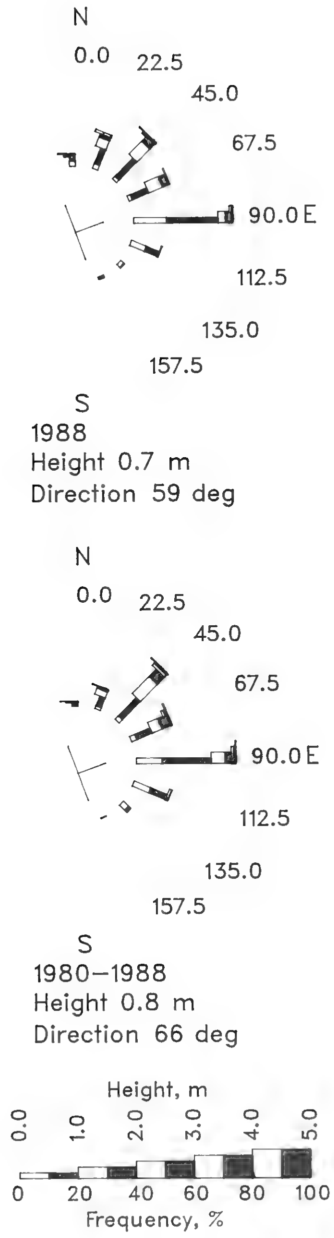


Figure 13. Annual wave roses

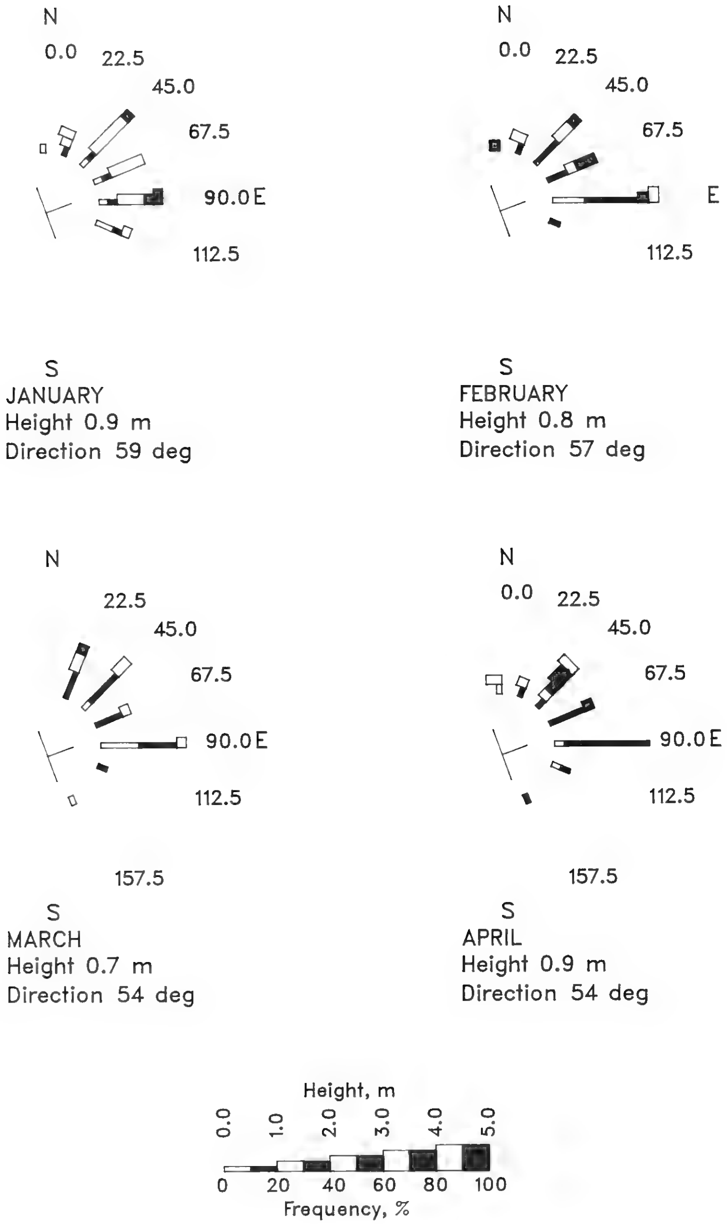


Figure 14. Monthly wave roses for 1988 (Sheet 1 of 3)

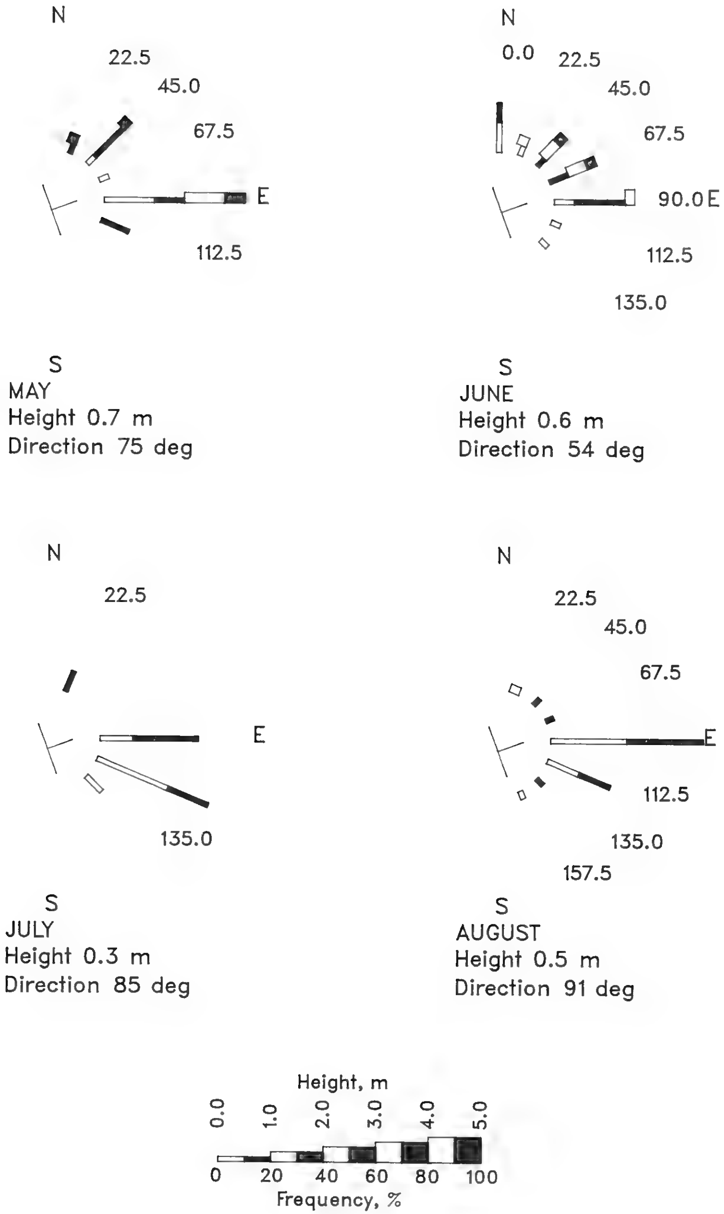
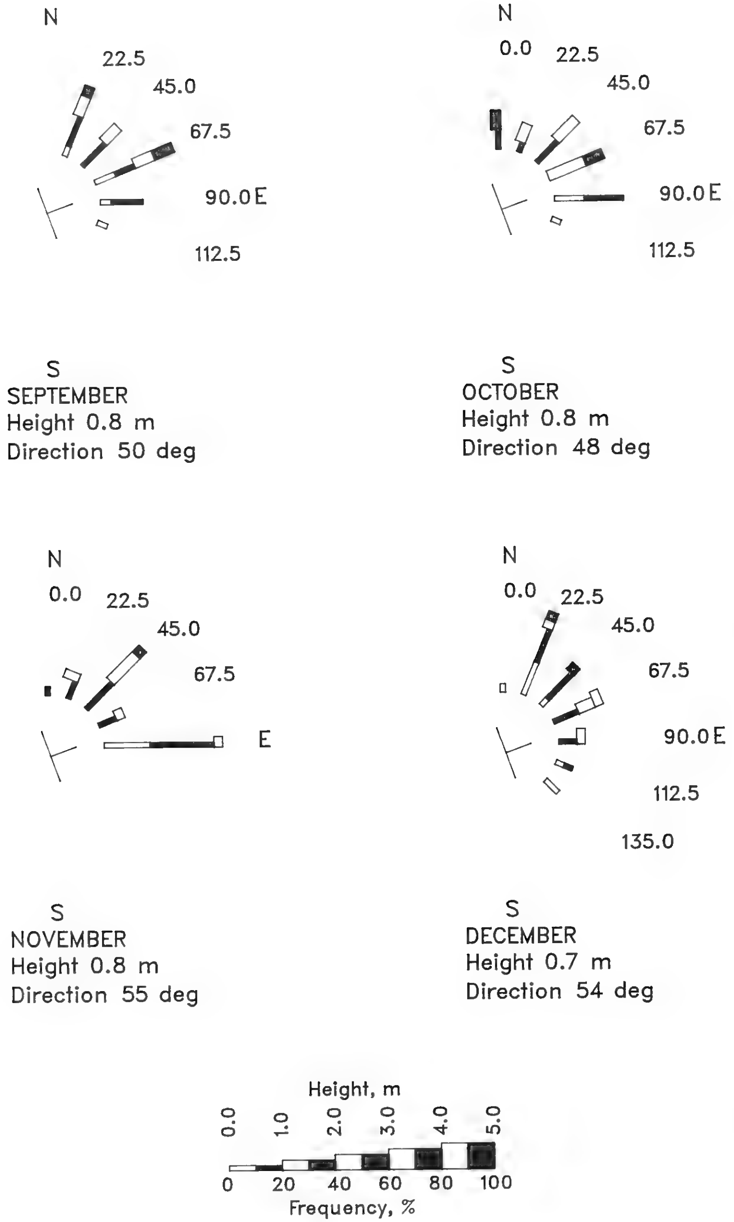


Figure 14. (Sheet 2 of 3)



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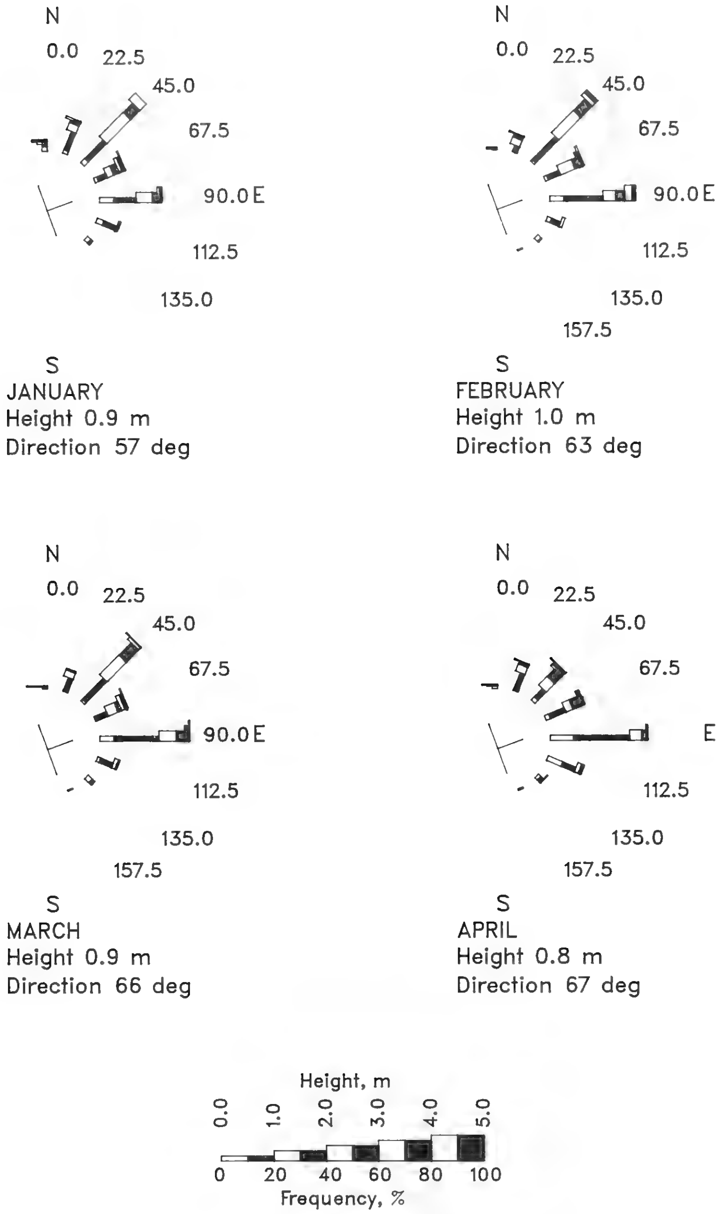


Figure 15. Monthly wave roses for 1980 through 1988 (Sheet 1 of 3)

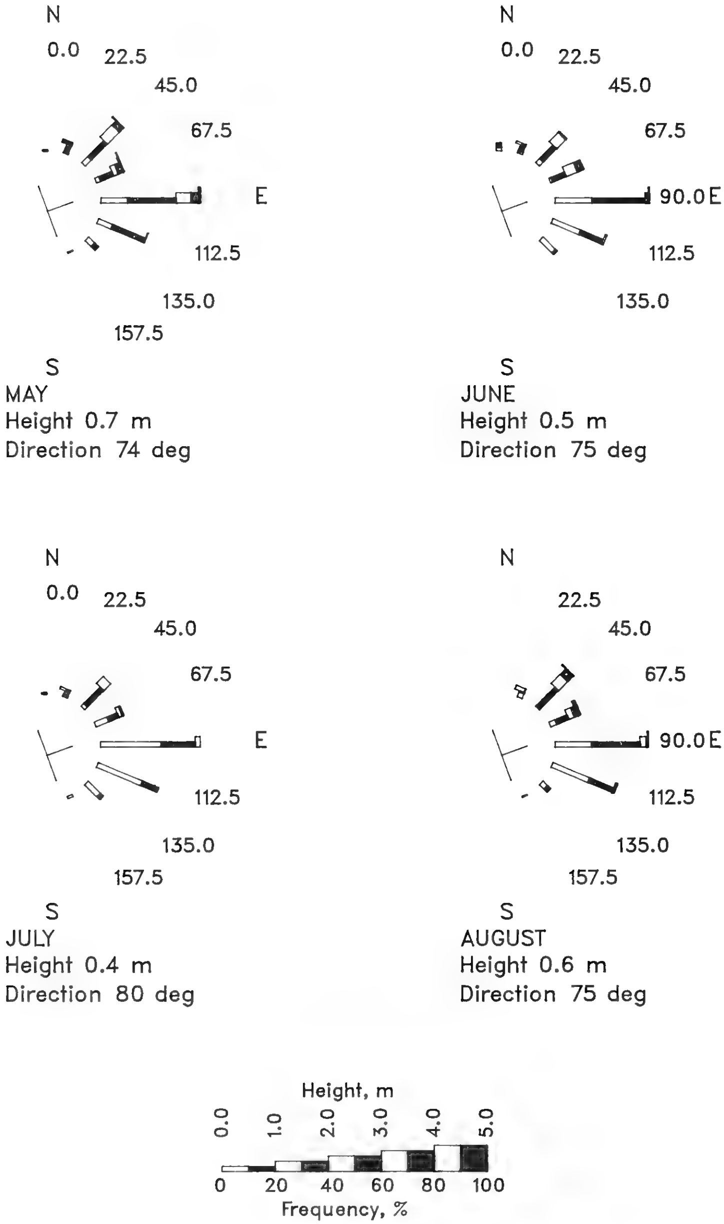


Figure 15. (Sheet 2 of 3)

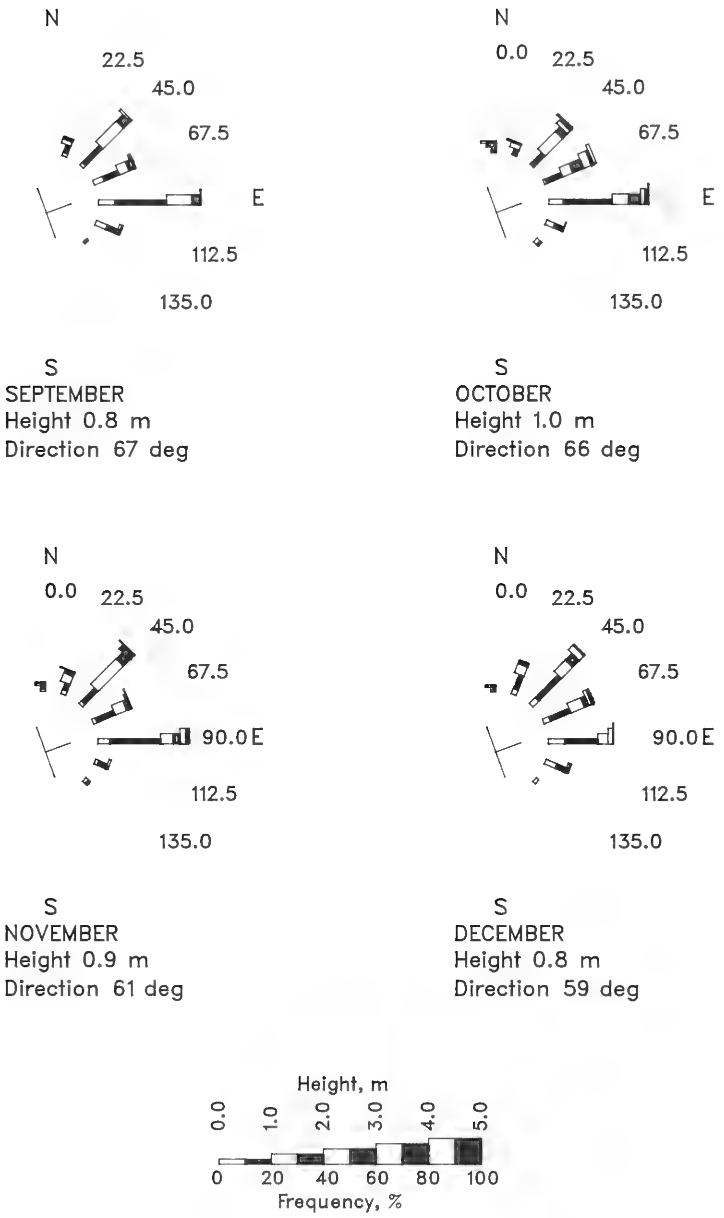


Figure 15 (Sheet 3 of 3)

PART IV: CURRENTS

44. Surface current speed and direction at the FRF are influenced by winds, waves, and, indirectly, by the bottom topography. The extent of the respective influence varies daily. However, winds tend to dominate the currents at the seaward end of the pier, whereas waves dominate within the surf zone.

Observations

45. Near 0700 EST, daily observations of surface current speed and direction were made at (a) the seaward end of the pier, (b) the midsurf position on the pier, and (c) 10 to 15 m from the beach 500 m updrift of the pier. Surface currents were determined by observing the movement of dye on the water surface.

Results

46. Annual mean and mean currents for 1980 through 1988 are presented in Table 6 and in Figure 16. Figure 16 shows the daily and average annual measurements at the beach, pier midsurf, and pier end locations. Since the relative influences of the winds and waves vary with position from shore, the current speeds and, to some extent, direction vary at the beach, midsurf, and pier end locations. Magnitudes generally are largest at the midsurf location and lowest at the end of the pier.

Table 6

Mean Longshore Surface Currents*

Month	Pier End, cm/sec 1988	Pier End, cm/sec 1980-1988	Pier Midsurf, cm/sec 1988	Pier Midsurf, cm/sec 1980-1988	Beach, cm/sec 1988	Beach, cm/sec 1980-1988
Jan	7	16	10	20	4	13
Feb	15	18	3	11	15	12
Mar	14	16	3	14	33	14
Apr	8	11	-12	1	6	8
May	21	11	14	-4	-3	-1
Jun	4	5	-15	-8	-10	-5
Jul	10	3	12	-16	0	-9
Aug	-10	8	-31	-12	-28	-5
Sep	4	7	-26	-6	-30	-1
Oct	18	9	-1	0	5	2
Nov	13	14	16	8	7	11
Dec	-1	14	-13	14	7	8
Annual	9	11	-3	2	1	4

* + = southward; - = northward.

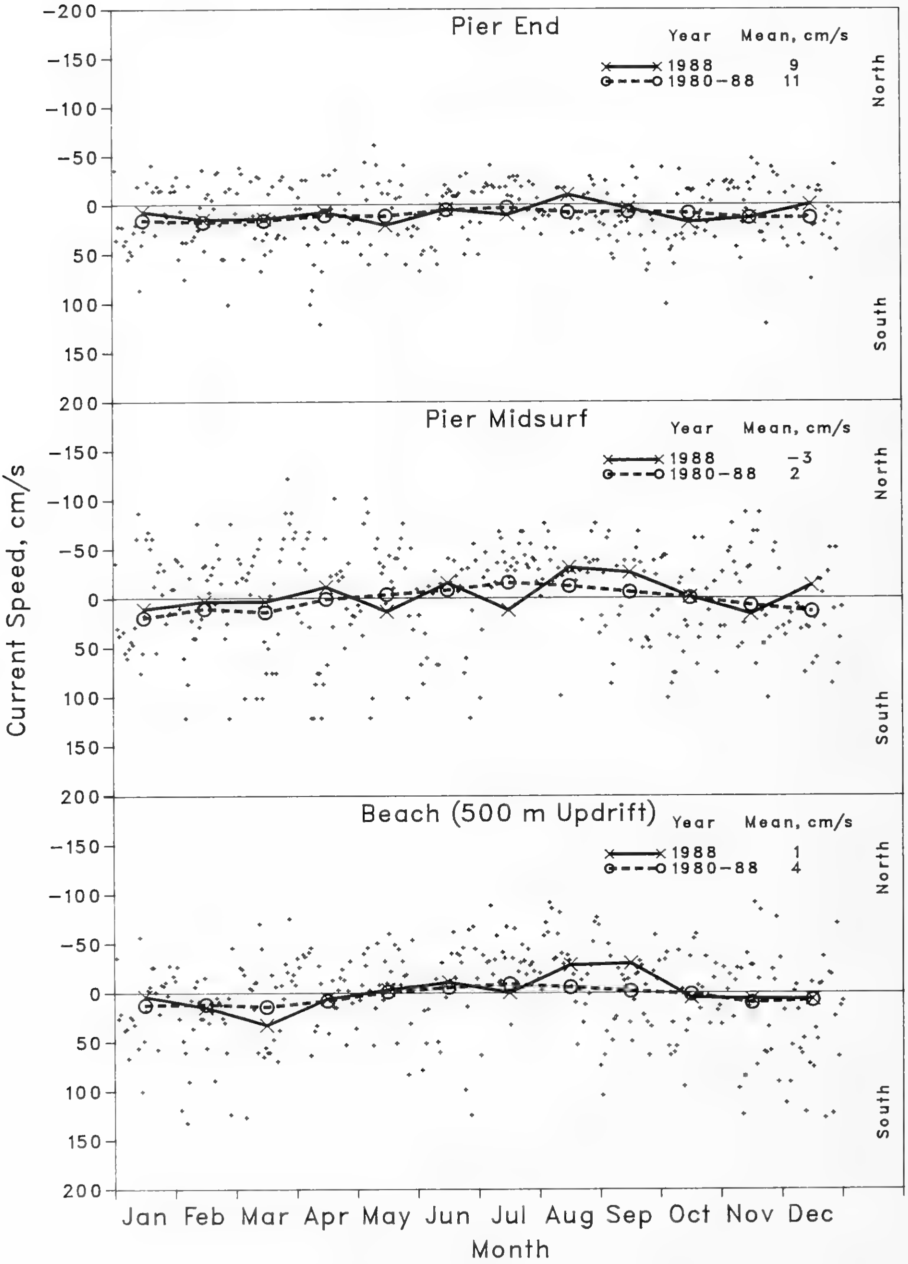


Figure 16. Daily current speeds and directions with monthly means for 1988

PART V: TIDES AND WATER LEVELS

Measurement Instrument

47. Water level data were obtained from a NOAA/NOS control tide station (sta 865-1370) located at the seaward end of the research pier (Figure 2) by using a Leupold and Stevens, Inc. (Beaverton, OR) digital tide gage. This analog-to-digital recorder is a float-activated, negator-spring, counterpoised instrument that mechanically converts the vertical motion of a float into a coded, punched paper tape record. The below-deck installation at pier sta 19+60 consisted of a 30.5-cm-diam stilling well with a 2.5-cm orifice and a 21.6-cm-diam float.

48. Operation and tending of the tide gage conformed to NOS standards. The gage was checked daily for proper operation of the punch mechanism and for accuracy of the time and water level information. The accuracy was determined by comparing the gage level reading with a level read from a reference electric tape gage. Once a week, a heavy metal rod was lowered down the stilling well and through the orifice to ensure free flow of water into the well. During the summer months, when biological growth was most severe, divers inspected and cleaned the orifice opening as required.

49. The tide station was inspected quarterly by a NOAA/NOS tide field group. Tide gage elevation was checked using existing NOS control positions, and the equipment was checked and adjusted as needed. Both NOS and FRF personnel also reviewed procedures for tending the gage and handling the data. Any specific comments on the previous months of data were discussed to ensure data accuracy.

50. Digital paper tape records of tide heights taken every 6 min were analyzed by the Tides Analysis Branch of NOS. An interpreter created a digital magnetic computer tape from the punch paper tape, which was then processed on a large computer. First, a listing of the instantaneous tidal height values was created for visual inspection. If errors were encountered, a computer program was used to fill in or recreate bad or missing data using correct values from the nearest NOS tide station and accounting for known time lags and elevation anomalies. The data were plotted, and a new listing was generated and rechecked. When the validity of the data had been confirmed, monthly tabulations of daily highs and lows, hourly heights (instantaneous

height selected on the hour), and various extreme and/or mean water level statistics were computed.

Results

51. Tides at the FRF are semidiurnal with both daily high and low tides approximately equal. Tide height statistics are presented in Table 7. Figure 17 plots the monthly tide statistics for all available data, and Figure 18 compares the distribution of daily high- and low-water levels and hourly tide heights. The monthly or annual mean sea level (MSL) reported is the average of the hourly heights, whereas the mean tide level is midway between mean high water (MHW) and mean low water (MLW), which are the averages of the daily high- and low-water levels, respectively, relative to NGVD. Mean range (MR) is the difference between MHW and MLW levels, and the lowest water level for the month is the extreme low (EL) water, while the highest water level is the extreme high (EH) water level.

Table 7

Tide Height Statistics*

Month or Year	Mean High Water	Mean Tide Level	Mean Sea Level	Mean Low Water	Mean Range	Extreme High	Date	Extreme Low	Date
					1988				
Jan	-	-	-	Gage Inoperative		-	-	-	-
Feb	47	7	7	-33	80	85	28	-69	14
Mar	42	2	3	-37	79	80	19	-58	20
Apr	58	19	19	-21	79	129	13	-62	18
May	51	10	11	-30	81	88	6	-55	14
Jun	50	10	10	-29	79	112	3	-51	6
Jul	42	1	2	-39	81	74	1	-55	30
Aug	46	5	6	-36	82	77	31	-60	29
Sep	46	6	7	-34	80	89	26	-60	23
Oct	46	8	8	-31	77	83	25	-63	26
Nov	42	3	4	-36	78	93	24	-62	20
Dec	37	-2	-2	-41	78	73	13	-72	21
1988	46	6	7	-33	79	129	Apr	-72	Dec
					Prior Years				
1987	55	15	16	-24	79	113	Jan	-63	Nov
1986	60	13	13	-35	95	123	Dec	-108	Jan
1985	59	10	11	-37	96	136	Dec	-93	Apr
1984	64	16	16	-32	97	147	Oct	-77	Jul
1983	68	19	19	-30	98	143	Jan	-73	Mar
1982	58	8	9	-42	99	127	Oct	-108	Feb
1981	59	8	9	-42	101	149	Nov	-110	Apr
1980	59	8	8	-43	102	118	Mar	-119	Mar
1979	60	9	9	-43	103	121	Feb	-95	Sep
1979-1988	59	11	12	-36	95	147	Nov 1981	-119	Mar 1980

* Measurements are in centimeters.

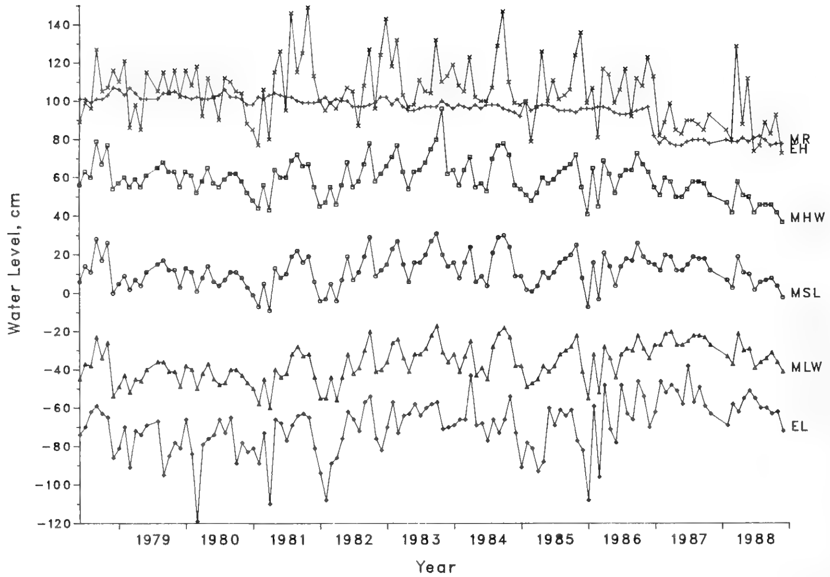


Figure 17. Monthly tide and water level statistics relative to NGVD

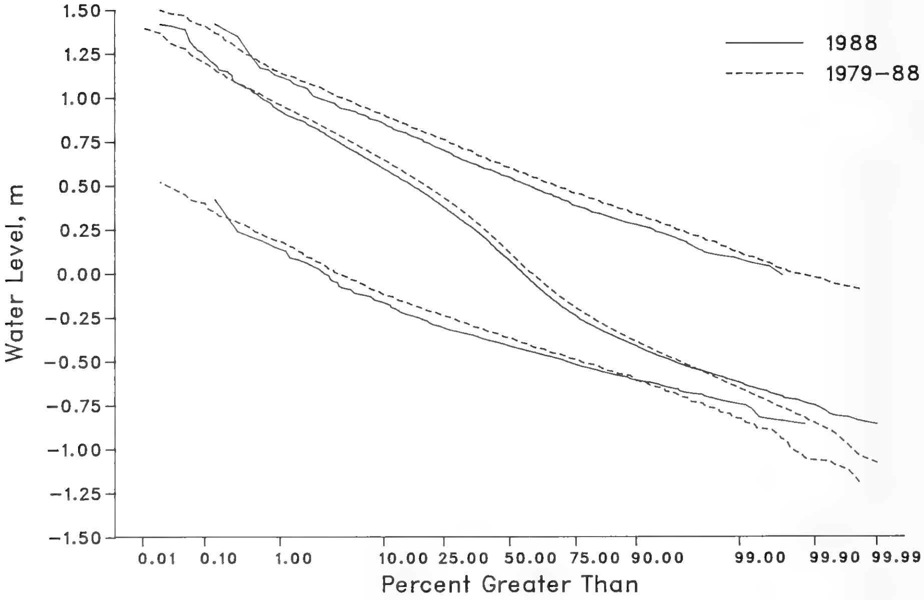


Figure 18. Distributions of hourly tide heights and high- and low-water levels

PART VI: WATER CHARACTERISTICS

52. Monthly averages of daily measurements of surface water temperature, visibility, and density at the seaward end of the FRF pier are given in Table 8. The summaries represent single observations made near 0700 EST and, therefore, may not reflect daily average conditions since such characteristics can change within a 24-hr period. Large temperature variations were common when there were large differences between the air and water temperatures and variations in wind direction. From past experience, persistent onshore winds move warmer surface water toward the shoreline, although offshore winds cause colder bottom water to circulate shoreward resulting in lower temperatures.

Table 8

Mean Surface Water Characteristics

	Temperature deg C		Visibility m		Density g/cm^3	
Month	1988	1980-1988	1988	1980-1988	1988	1980-1988
Jan	4.6	5.6	1.4	1.2	1.0227	1.0234
Feb	5.6	4.7	2.2	1.7	1.0237	1.0231
Mar	7.3	6.6	2.7	1.5	1.0243	1.0229
Apr	10.5	10.8	1.5	1.9	1.0242	1.0226
May	15.5	15.2	2.2	2.3	1.0219	1.0222
Jun	18.9	19.3	2.5	3.4	1.0220	1.0215
Jul	21.3	21.7	3.8	3.8	1.0241	1.0218
Aug	21.9	23.2	4.7	3.2	1.0239	1.0209
Sep	21.6	22.6	2.7	2.3	1.0230	1.0211
Oct	17.7	18.9	1.5	1.5	1.0237	1.0218
Nov	14.7	14.7	1.5	1.0	1.0250	1.0230
Dec	9.1	10.1	1.8	1.1	1.0259	1.0235
Annual	14.1	14.4	2.4	2.1	1.0237	1.0223

Temperature

53. Daily sea surface water temperatures (Figure 19) were measured with an NOS water sampler and thermometer. Monthly mean water temperatures (Table 8) varied with the air temperatures (see Table 2).

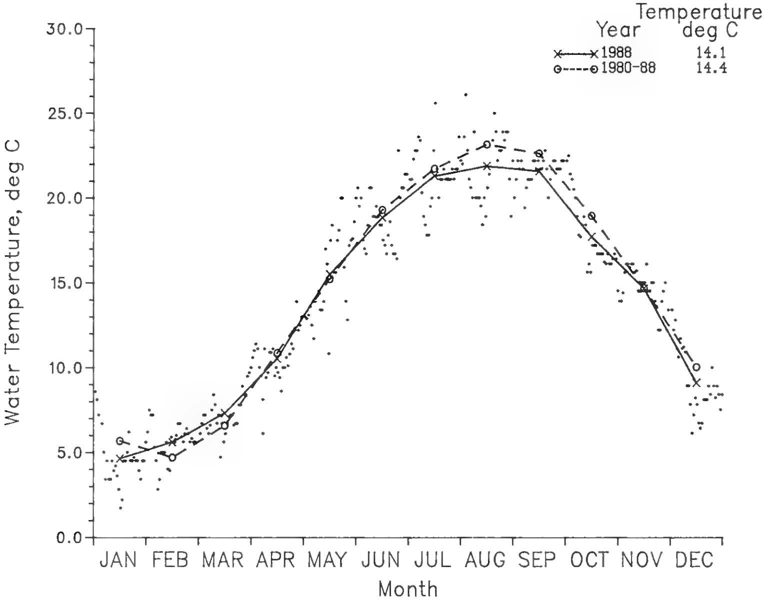


Figure 19. Daily water temperature values with monthly means

Visibility

54. Visibility in coastal nearshore waters depends on the amount of salts, soluble organic material, detritus, living organisms, and inorganic particles in the water. These dissolved and suspended materials change the absorption and attenuation characteristics of the water which vary daily and yearly.

55. Visibility was measured with a 0.3-m-diam Secchi disk and, similar to water temperature, variation was related to onshore and offshore winds. Onshore winds moved warm clear surface water toward shore, whereas offshore winds brought up colder bottom water with large concentrations of suspended matter. Figure 20 presents the daily and monthly mean surface visibility values for the year. Large variations were common, and visibility less than 1 m was expected in any month. Monthly means are given in Table 8.

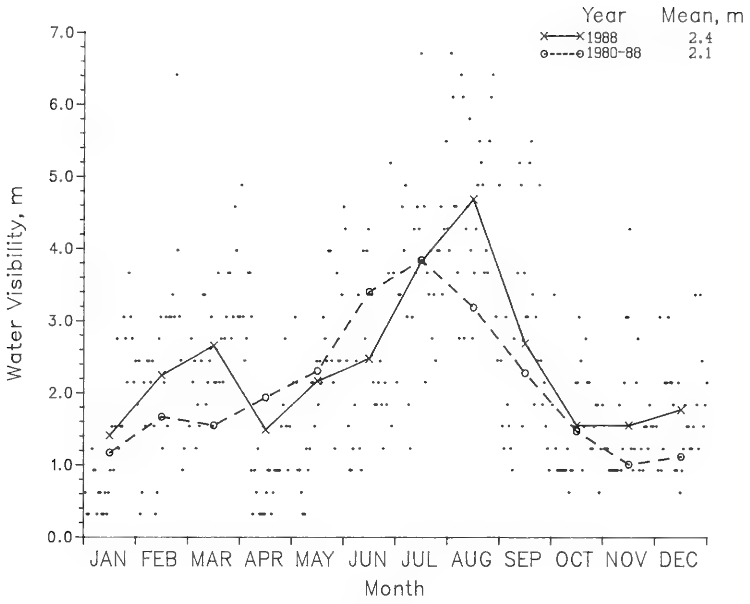


Figure 20. Daily water visibility values with monthly means

Density

56. Daily and monthly mean surface density values, plotted in Figure 21, were measured with a hydrometer. Monthly means are also given in Table 8.

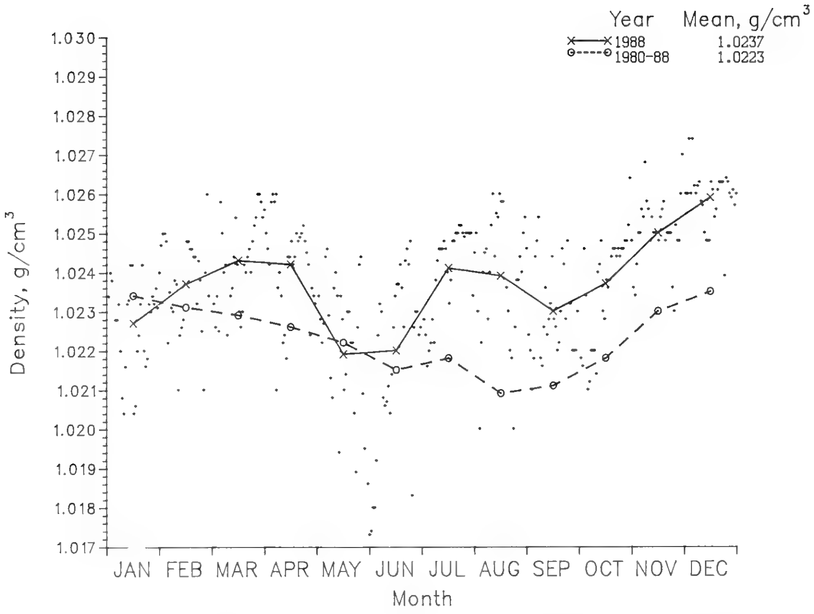


Figure 21. Daily water density values with monthly means

PART VII: SURVEYS

57. Waves and currents interacting with bottom sediments produce changes in the beach and nearshore bathymetry. These changes can occur very rapidly in response to storms or slowly as a result of persistent but less forceful seasonal variations in wave and current conditions.

58. Nearshore bathymetry at the FRF is characterized by regular shore-parallel contours, a moderate slope, and a barred surf zone (usually an outer storm bar in water depths of about 4.5 m and an inner bar in water depths between 1.0 and 2.0 m). This pattern is interrupted in the immediate vicinity of the pier where a permanent trough runs under much of the pier, ending in a scour hole where depths can be up to 3.0 m greater than the adjacent bottom (Figure 22). This trough, which apparently is the result of the interaction of waves and currents with the pilings, varies in shape and depth with changing wave and current conditions. The effect of the pier on shore-parallel contours occurs as far as 300 m away, and the shoreline may be affected up to 350 m from the pier (Miller, Birkemeier, and DeWall 1983).

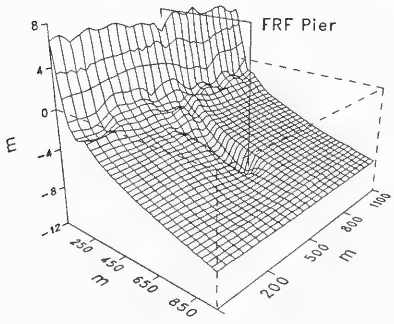


Figure 22. Permanent trough under the FRF pier, 8 July 1988

59. To document the temporal and spatial variability in bathymetry, surveys were conducted approximately monthly of an area extending 600 m north and south of the pier and approximately 950 m offshore. Contour maps resulting from these surveys along with plots of change in elevation between surveys are given in Appendix A.

60. All surveys utilized the Coastal Research Amphibious Buggy (CRAB), a 10.7-m-tall amphibious tripod, and a Zeiss electronic surveying system described by Birkemeier and Mason (1984). The profile locations are shown in each figure in Appendix A. Survey accuracy was about ±3 cm horizontally and vertically. Monthly soundings along both sides of the FRF pier were collected by lowering a weighted measuring tape to the bottom and recording the distance below the pier deck. Soundings were taken midway between the pier pilings to minimize errors caused by scour near the pilings.

61. A history of bottom elevations below Gages 645 and 625 is presented in Figure 23 for their respective pier stations of sta 7+80 (238 m) and sta 19+00 (579 m) along with intermediate locations, 323 and 433 m.

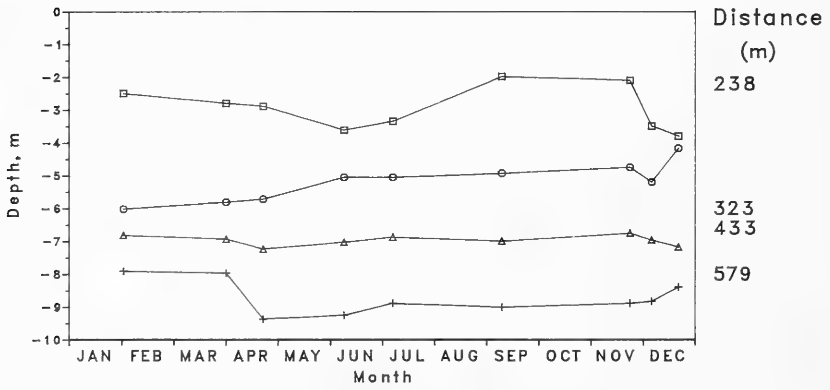


Figure 23. Time-history of bottom elevations at selected locations under the FRF pier

PART VIII: PHOTOGRAPHY

Aerial Photographs

62. Aerial photography was taken quarterly using a 23-cm aerial mapping camera at a scale of 1:12,000. All coverage was at least 60-percent overlap, with flights flown as closely as possible to low tide between 1000 and 1400 EST with less than 10-percent cloud cover. The flight lines covered are shown in Figure 24. Figure 25 is a sample of the imagery obtained on 12 August 1988; the available aerial photographs for the year are:

Date	Flight Lines	Format
6 Jan	2	Color
	3	B/W
25 Apr	2	Color
	3	B/W
12 Aug	Part of 1	B/W
	3	B/W
27 Sep	2	Color
9 Oct	3	B/W
	2	Color
	Rest of 1	B/W

Beach Photographs

63. Daily color slides of the beach were taken using a 35-mm camera from the same location on the pier looking north and south (Figure 26). The location from which each picture was taken, as well as the date, time, and a brief description of the picture, was marked on the slides.

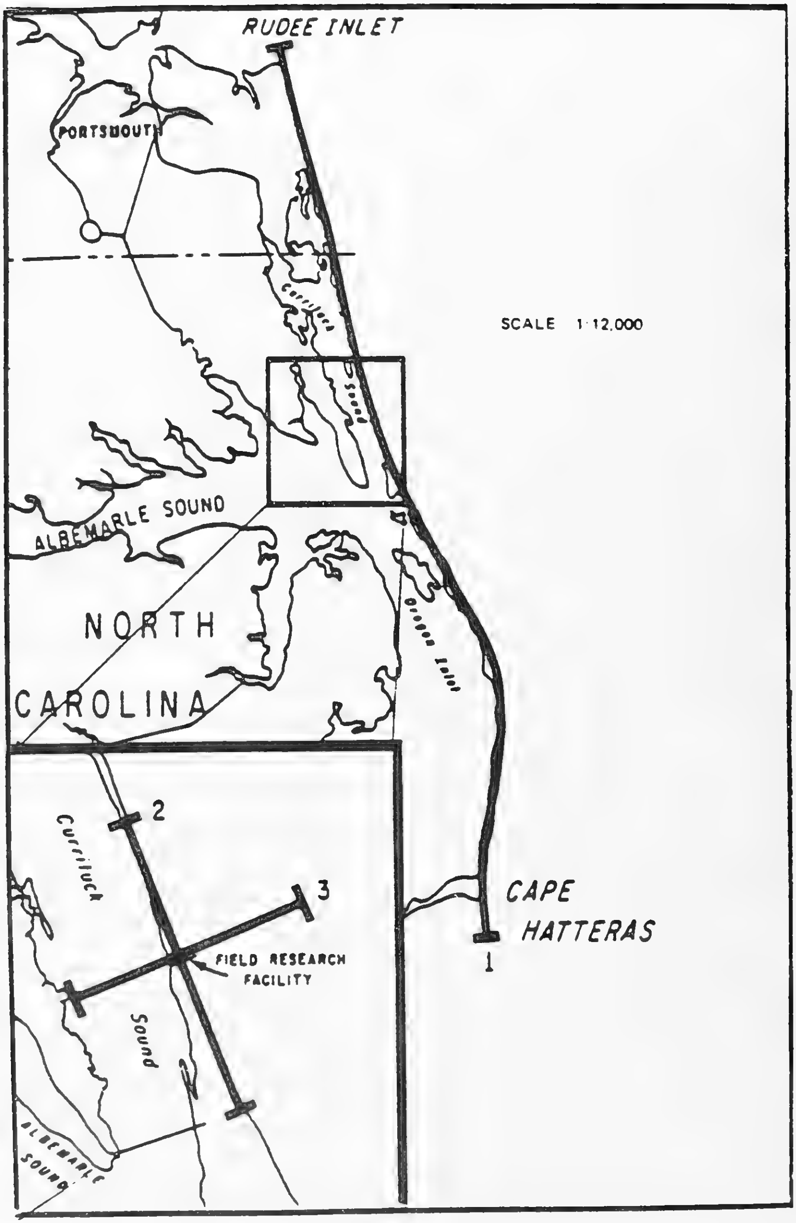


Figure 24. Aerial photography flight lines

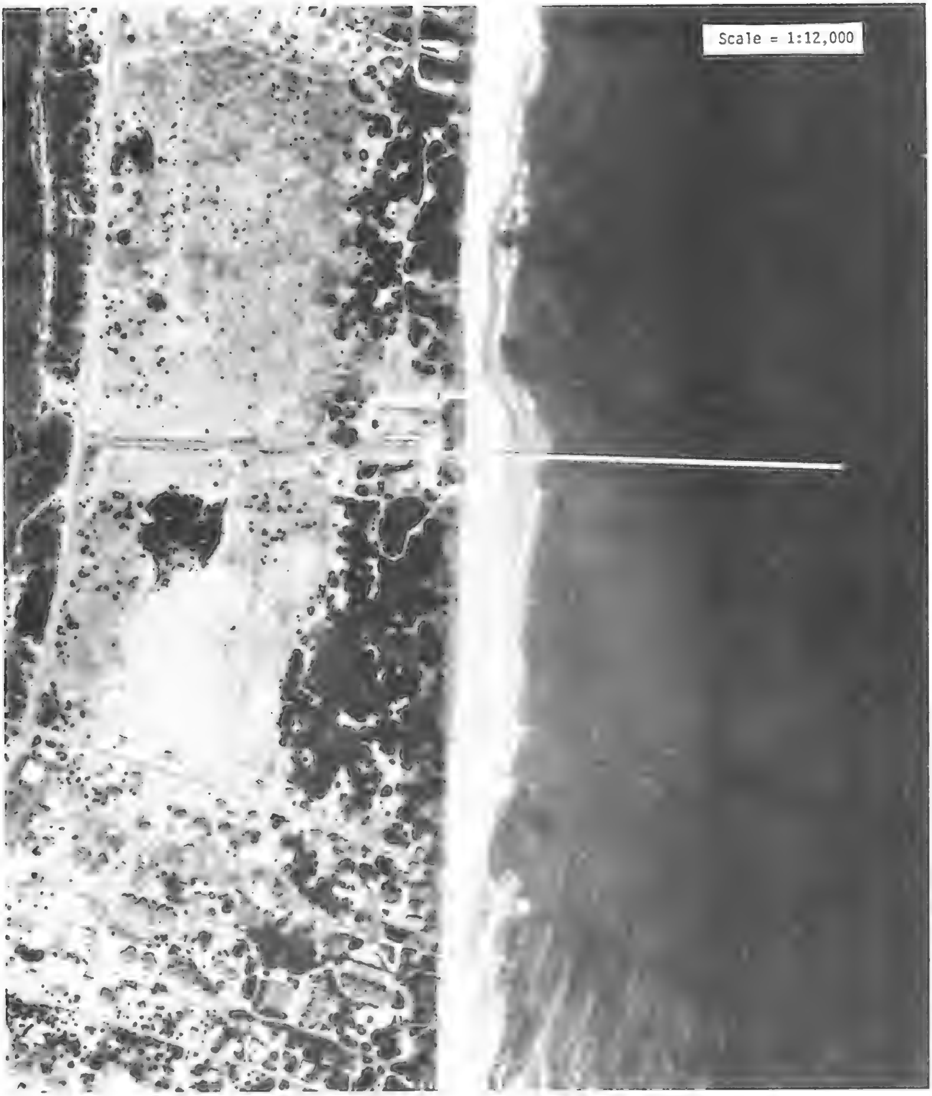
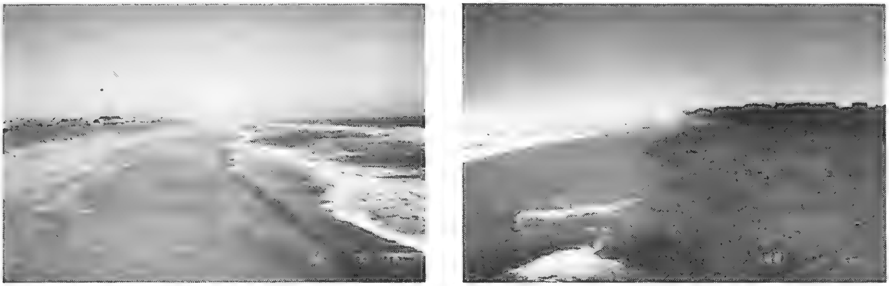
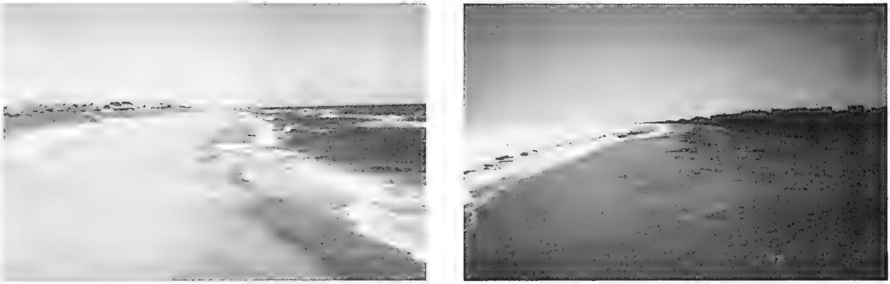


Figure 25. Sample aerial photograph, 12 August 1988

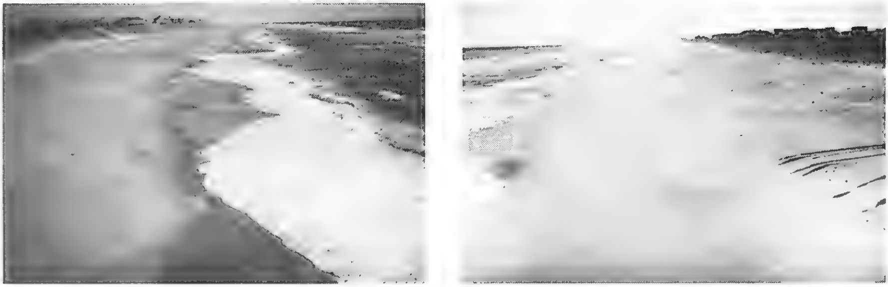
North View South View



a. 16 January 1988



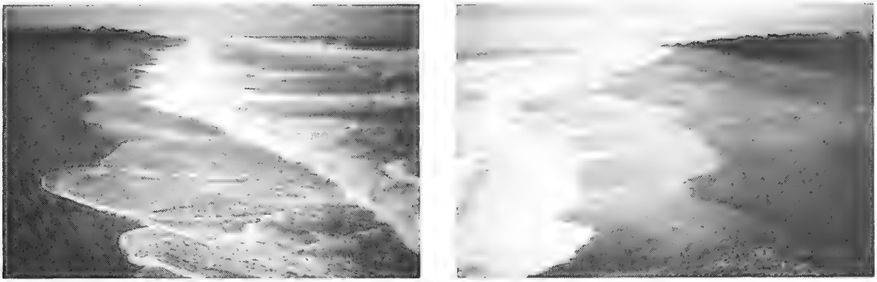
b. 13 February 1988



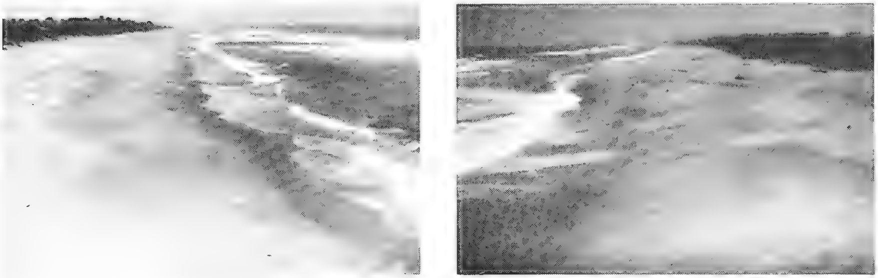
c. 11 March 1988

Figure 26. Beach photos looking north and south from the FRF pier (Sheet 1 of 4)

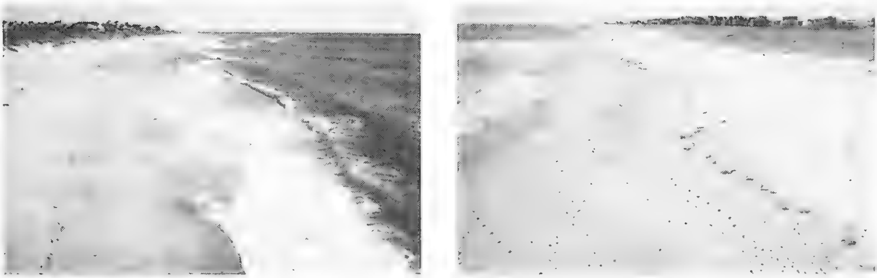
North View South View



a. 12 April 1988



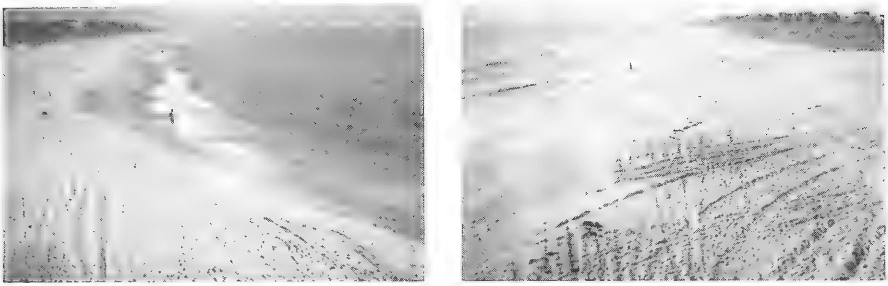
b. 16 May 1988



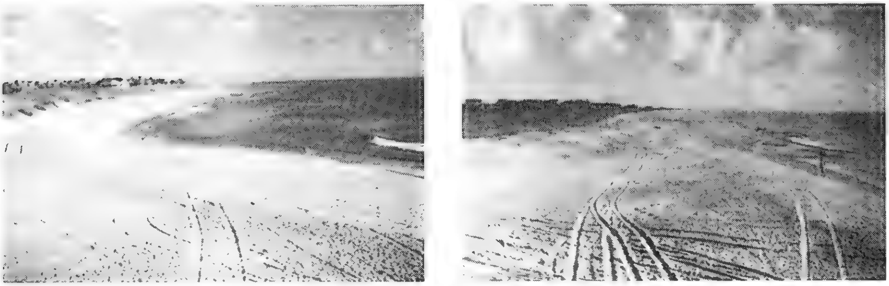
c. 12 June 1988

Figure 26. (Sheet 2 of 4)

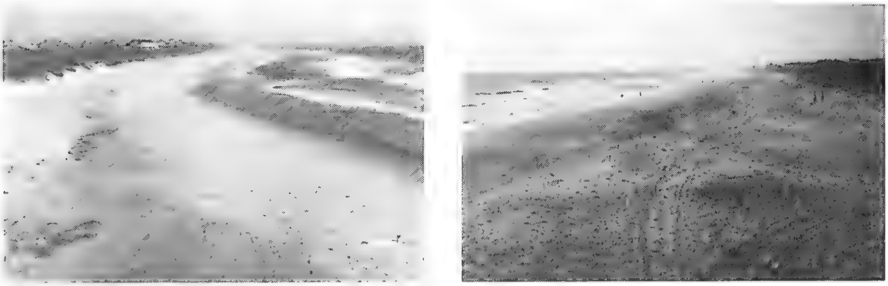
North View South View



a. 15 July 1988



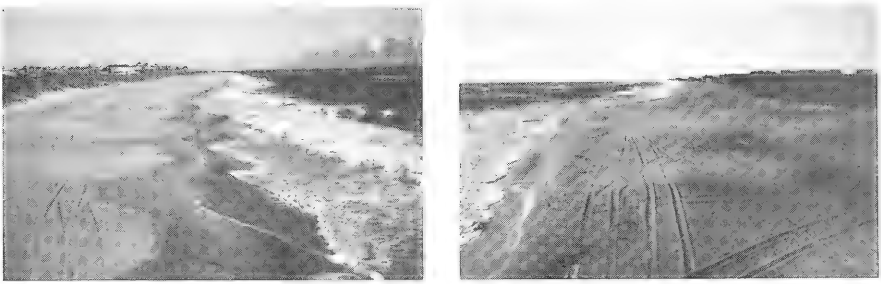
b. 12 August 1988



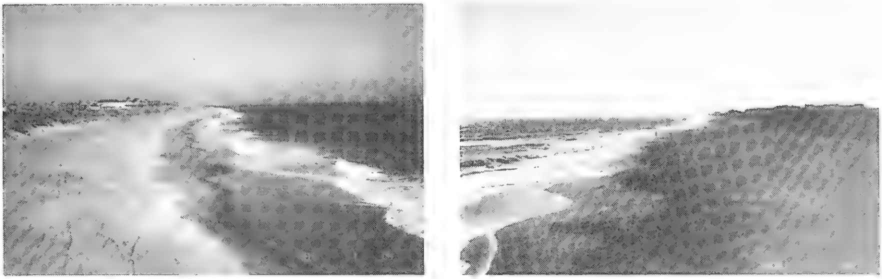
c. 3 September 1988

Figure 26. (Sheet 3 of 4)

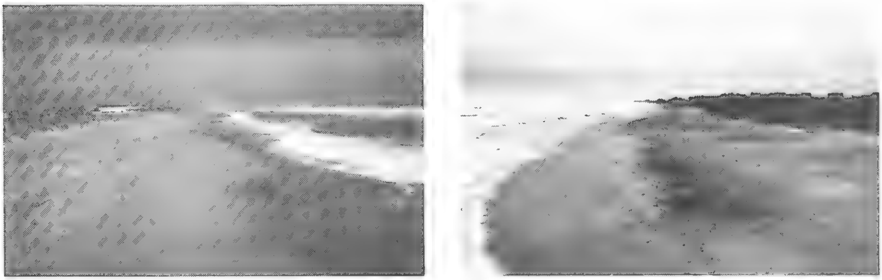
North View South View



a. 13 October 1988



b. 14 November 1988



c. 15 December 1988

Figure 26. (Sheet 4 of 4)

PART IX: STORMS

64. This section discusses storms (defined here as times when the wave height parameter, H_{mo}, equaled or exceeded 2 m at the seaward end of the FRF pier). Sample spectra from Gage 630 are given in Appendix B. Prestorm and/or poststorm bathymetry diagrams are given in Appendix A. Tracking information was provided by NOAA Daily Weather Maps (US Department of Commerce 1988).

<u>3 January 1988 (Figure 27)</u>

65. Early on 2 January, strong onshore winds (from north-northeast) generated by a high pressure system centered over Illinois began to affect the FRF. Late on 3 January, the maximum wind speeds exceeded 14 m/sec and the maximum H_{mo} (Gage 625) of 2.19 m (T_p = 7.53 sec) was recorded. Precipitation totaled 27 mm.

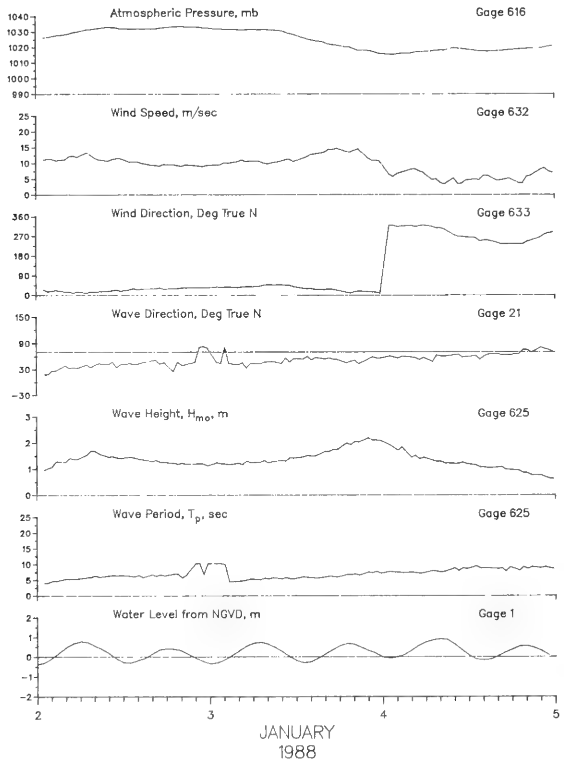


Figure 27. Data for 3 January 1988 storm

7-8 January 1988 (Figure 28)

66. Onshore winds, generated by a Canadian high pressure system, were reinforced by the formation of a storm off the NC coast late on 7 January. The storm moved rapidly up the coast and reached Maine by 9 January. Peak winds (from northeast) exceeded 16 m/sec at 0242 EST on 8 January. Several hours later, the maximum H_{mo} (Gage 625) of 2.85 (T_p = 7.76 sec) and minimum atmospheric pressure of 1011.3 mb were recorded. Precipitation totaled 25 mm.

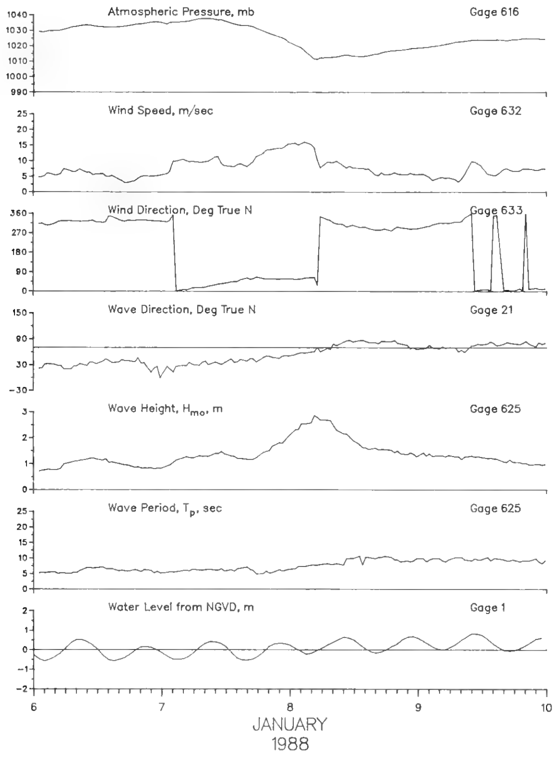


Figure 28. Data for 7-8 January 1988 storm

14 January 1988 (Figure 29)

67. A strong high pressure system centered over Illinois produced strong onshore winds (from northeast) at the FRF beginning late on 13 January and continuing through the 14th. The maximum wind speed (exceeding 17 m/sec) and the maximum H_{mo} (Gage 625) of 2.50 (T_p = 7.11 sec) were both recorded at 0700 EST on the 14th.

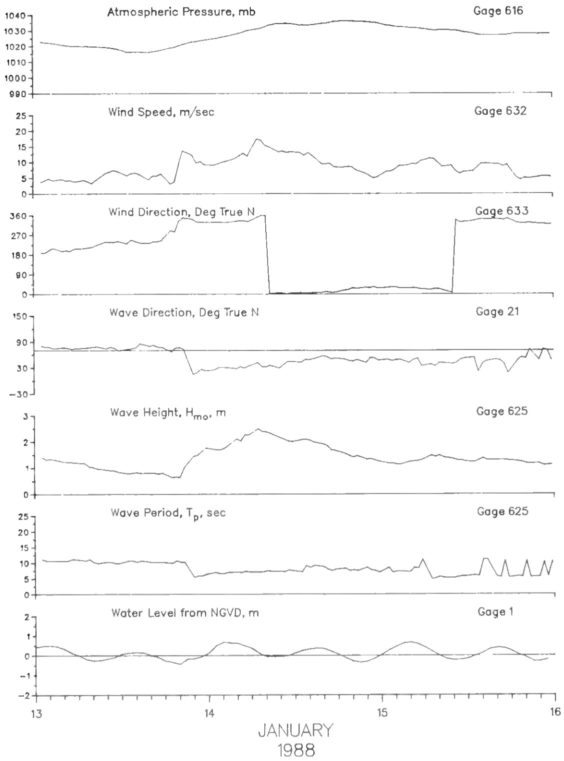


Figure 29. Data for 14 January 1988 storm

12 February 1988 (Figure 30)

68. This storm formed over Texas early on 10 February and rapidly intensified as it moved to the north-northeast. By 12 February, it was located over Lake Erie, and two weak secondary lows formed in the Atlantic (one off Cape Hatteras, NC). All three lows merged over New England by 13 February. Maximum onshore winds (from east-northeast) approached 7 m/sec at 0134 EST on 12 February followed several hours later by the maximum H_{mo} (Gage 625) of 2.25 m (T_p = 9.14 sec). Minimum atmospheric pressure was 1006.8 mb, and precipitation totaled 25 mm.

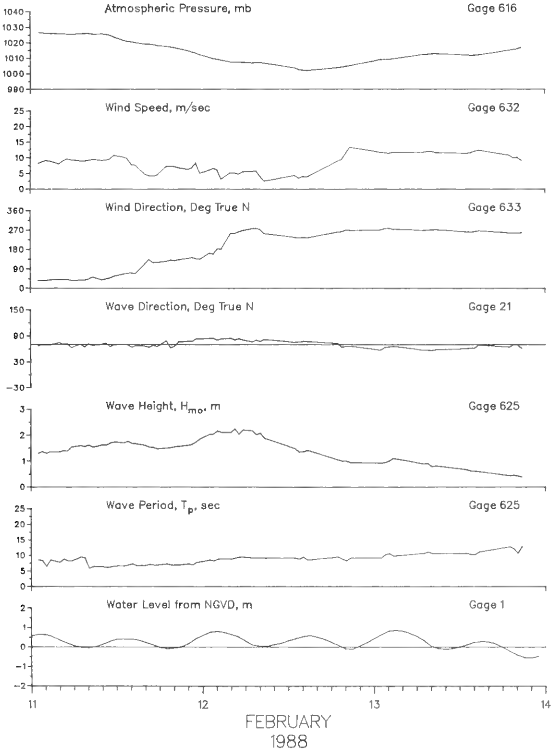


Figure 30. Data for 12 February 1988 storm

28 February 1988 (Figure 31)

69. Generically known as "Alberta Clipper," this storm roared out of Canada on 26 February and was located off Cape Hatteras, NC, by 28 February. Northerly winds exceeded 16 m/sec early on the 28th with the maximum H_{mo} (Gage 625) of 2.76 m (T_p = 8.00 sec) recorded the same morning. The minimum atmospheric pressure of 1004.4 mb occurred at 1442 EST on 27 February. There was no measurable precipitation with this storm.

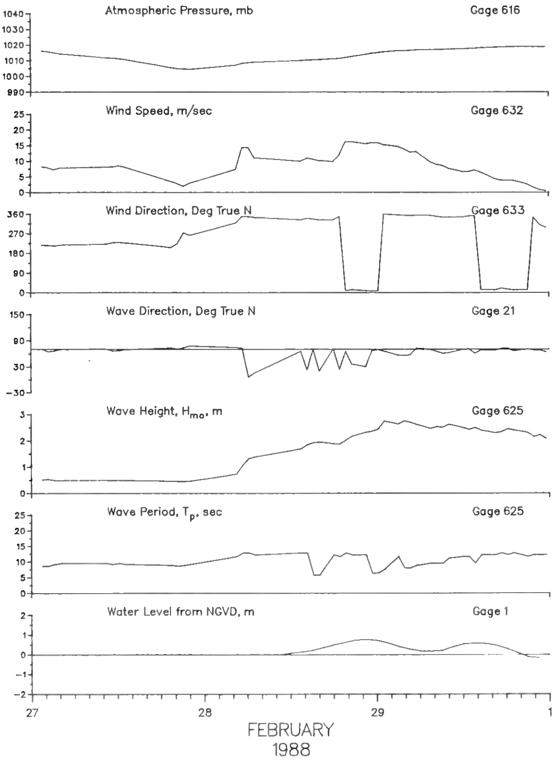


Figure 31. Data for 28 February 1988 storm

11 March 1988 (Figure 32)

70. This weak storm formed over Texas early on 9 March and tracked east. Centered over North Carolina on 10 March, the storm quickly moved offshore. Maximum wind speeds (from north-northeast) exceeded 15 m/sec at 2342 EST on 10 March. Wave heights exceeded 2 m only 3 hr with the maximum H_{mo} (Gage 625) of 2.2 m (T_p = 6.9 sec) occurring at 0208 EST on 11 March. The lowest atmospheric pressure of 999.2 mb was recorded at 0842 EST on 10 March. Precipitation totaled 4 mm.

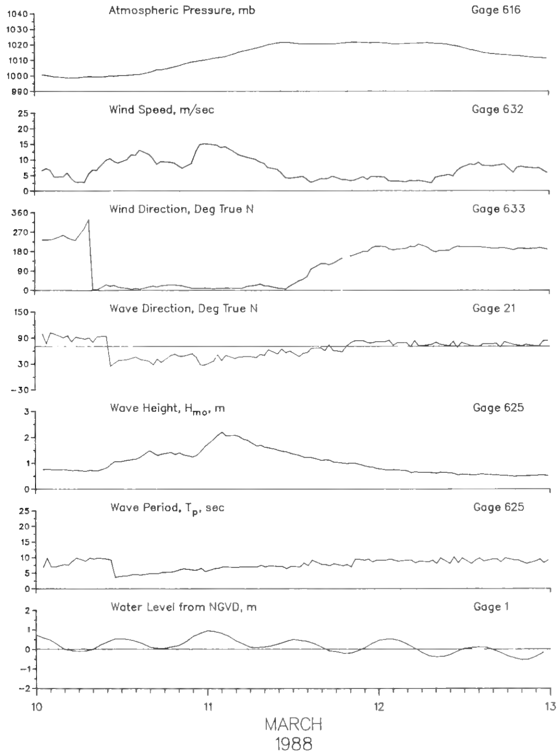


Figure 32. Data for 11 March 1988 storm

8 April 1988 (Figure 33)

71. This storm formed over the southwestern United States on 30 March and slowly strengthened as it approached the Great Lakes. It dropped to the southeast passing over the Virginia coast early on 8 April and rapidly moved into the Atlantic. On 8 April at 0734 EST, the maximum wind speeds (from north) neared 16 m/sec and the maximum H_{mo} (Gage 625) was 2.8 m (T_p = 9.85 sec). The minimum atmospheric pressure of 994.7 mb occurred early on 7 April. Precipitation amounted to 30 mm.

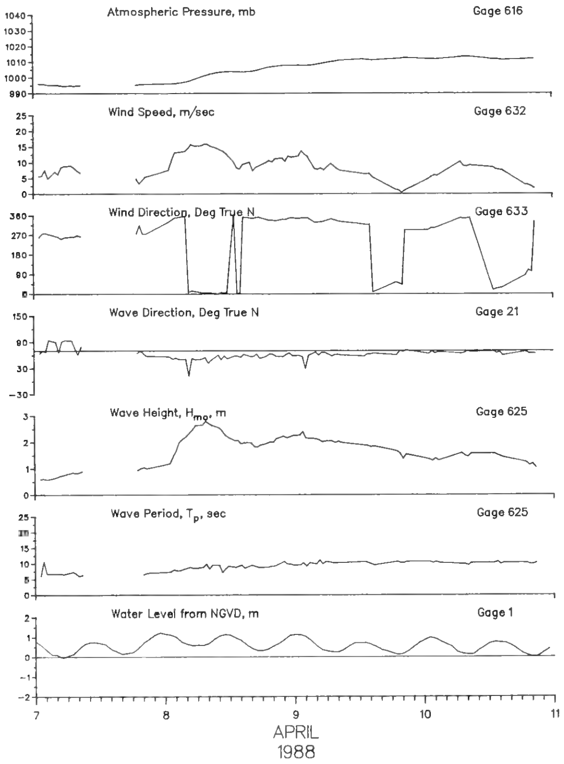


Figure 33. Data for 8 April 1988 storm

12-14 April 1988 (Figure 34)

72. After forming over the Gulf of Mexico on 10 April, this storm continued to strengthen as it tracked across the southeast. By 12 April, it was still well inland over Alabama; however, strong onshore winds were being generated at the FRF. As it continued to intensify, the forward movement of the storm slowed, finally moving offshore at Cape Hatteras, NC, on 13 April. This northeaster caused coastal erosion (resulting in the demise of several beach cottages) and flooding at a number of locations along the Outer Banks. Peak winds (from northeast) exceeded 21 m/sec early on 13 April with winds above 15 m/sec continuing for 37 hr. The minimum atmospheric pressure (1001.0 mb) occurred at 0700 EST on 13 April, and the maximum H_{mo} of 4.96 m (T_p = 10.24 sec) at Gage 630 occurred several hours later. Total precipitation was 47 mm.

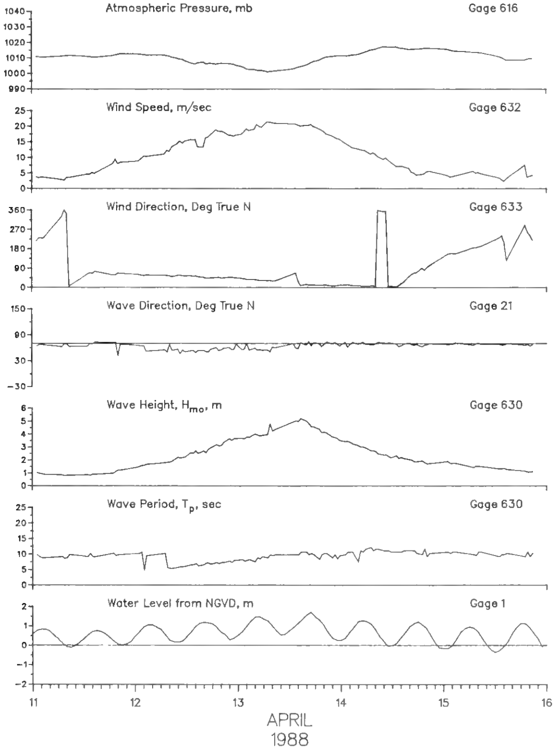


Figure 34. Data for 12-14 April 1988 storm

19 April 1988 (Figure 35)

73. This weak low pressure system began as a cold front over Louisiana on 18 April, rapidly moved to the northeast, and by 20 April moved well offshore. Maximum winds (from north) exceeded 19 m/sec on the afternoon of the 19th while the maximum H_{mo} (Gage 625) of 2.17 m (T_p = 6.92 sec) was attained several hours later. The minimum atmospheric pressure was 1000.8 mb, and precipitation totaled 19 mm.

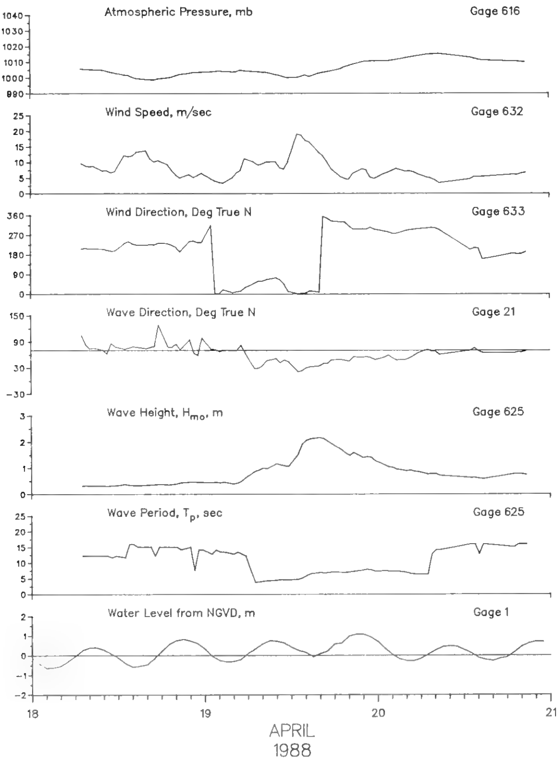


Figure 35. Data for 19 April 1988 storm

3-5 June 1988 (Figure 36)

74. This small coastal storm developed off Cape Hatteras, NC, early on 3 June and rapidly moved offshore. Maximum onshore winds (from north-northeast) exceeded 15 m/sec at 1934 EST on 3 June. This was closely followed by the maximum H_{mo} (Gage 625) of 2.40 m (T_p = 7.53 sec). Also on 3 June, the minimum atmospheric pressure of 1005.3 mb was recorded at 0842 EST. Total precipitation was 27 mm.

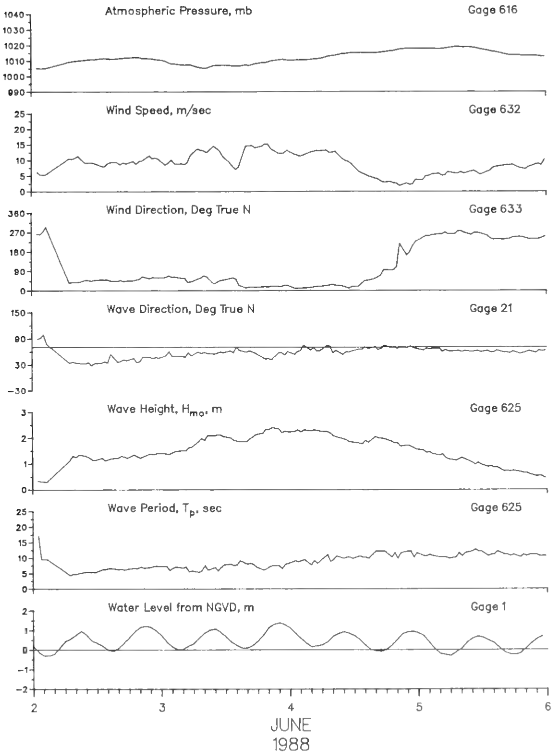


Figure 36. Data for 3-5 June 1988 storm

4 October 1988 (Figure 37)

75. On 3 October, this storm developed in the Gulf of Mexico off the Florida coast, quickly intensified as it moved up the eastern coast, and was located off Cape Hatteras, NC, early on 4 October. By the morning of 5 October, it was located off the New England coast. Maximum winds (from north-northeast) exceeding 16 m/sec peaked at 1000 EST on 4 October, and the maximum H_{mo} (Gage 625) of 2.29 m (T_p = 6.56 sec) was recorded at 0842 EST on the same day. The minimum atmospheric pressure of 1008 mb was recorded at 0700 EST on 4 October. Total precipitation was 25 mm.

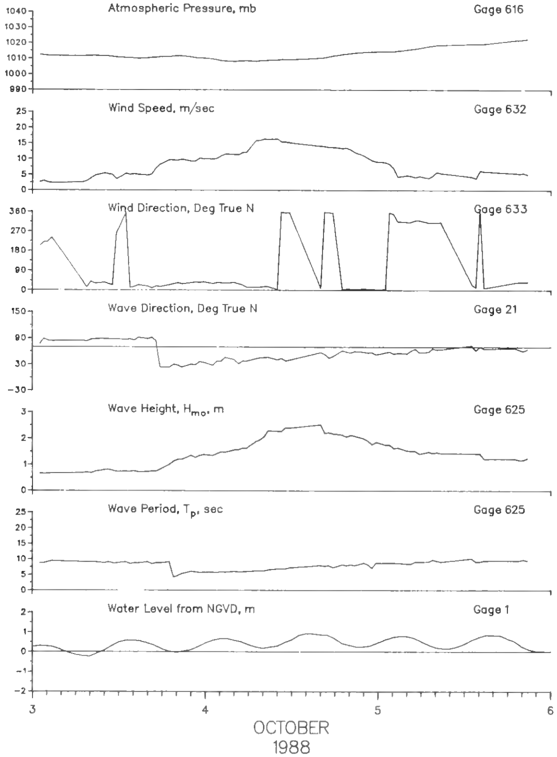


Figure 37. Data for 4 October 1988 storm

8 October 1988 (Figure 38)

76. Following the small storm on 4 October, winds continued onshore. With the addition of a strong Canadian high pressure system on 7 October, waves briefly exceeded 2 m. Maximum wind speeds (from north) recorded on 7 October exceeded 13 m/sec at 1334 EST; maximum H_{mo} of 2.07 m (T_p = 6.92 sec) at Gage 625 occurred at 0208 EST on 8 October.

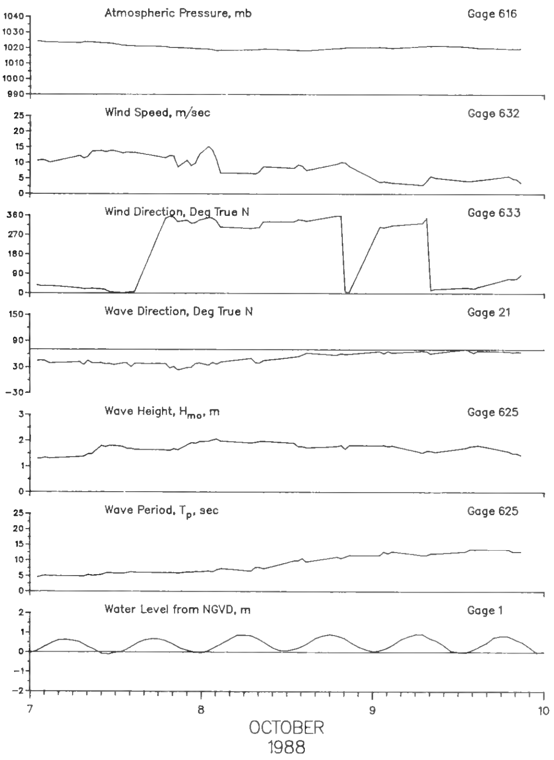


Figure 38. Data for 8 October 1988 storm

1 November 1988 (Figure 39)

77. Forming off the Georgia coast early on 1 November, this storm moved rapidly past the FRF and was located off New England by the next day. Maximum onshore winds (from northeast) peaked near 11 m/sec at 0208 EST on 1 November. At 1442 EST the maximum H_{mo} (Gage 625) of 2.41 m (T_p = 6.92 sec) was recorded, and at 1600 EST the minimum atmospheric pressure of 1003.3 mb was recorded. Total precipitation was 30 mm.

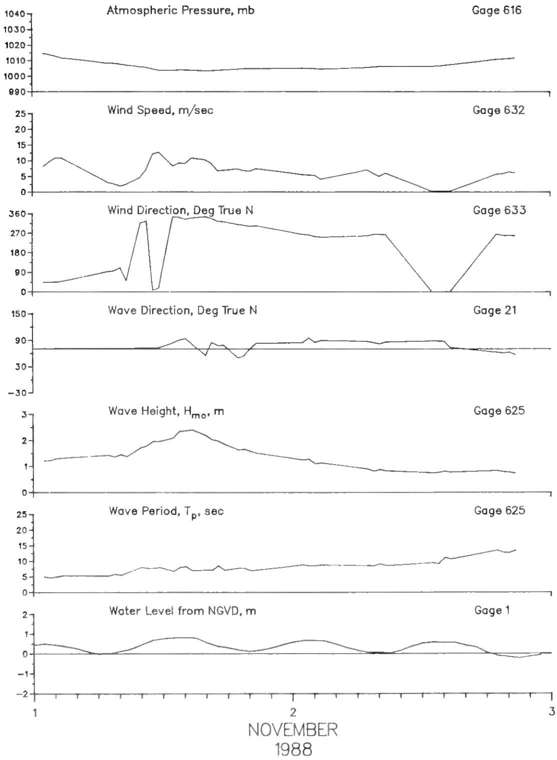


Figure 39. Data for 1 November 1988 storm

24 November 1988 (Figure 40)

78. Forming in the Gulf of Mexico, Tropical Storm Keith slowly followed a cold front across Florida on 22-23 November and continued to move to the northeast into the Atlantic on 24 November. The combination of a strong Canadian high pressure system and this offshore tropical storm produced storm waves on the 24th. Maximum onshore winds (from north-northeast) reached 14 m/sec at 0208 EST on the 24th followed shortly (0400 EST) by the minimum atmospheric pressure of 1010.1 mb. The maximum H_{mo} (Gage 111) of 2.47 m (T_p = 7.30 sec) was recorded at 1600 ESt. There was no precipitation.

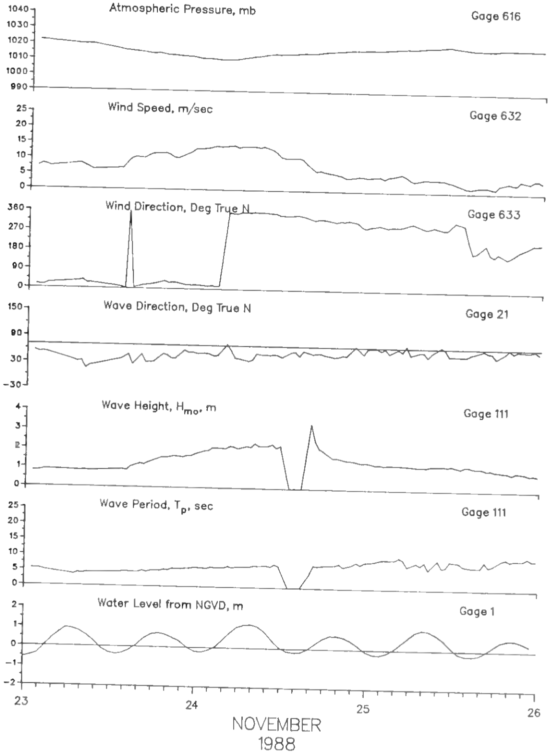


Figure 40. Data for 24 November 1988 storm

4 December 1988 (Figure 41)

79. A strong high pressure system centered over the southeastern United States in combination with a storm located in Canada produced strong winds on 4 December. Maximum winds (from north-northwest) exceeding 15 m/sec were recorded at 1034 EST on 4 December, and at 1142 EST the maximum H_{mo} (Gage 111) of 2.29 m (T_p = 7.31 sec) was recorded.

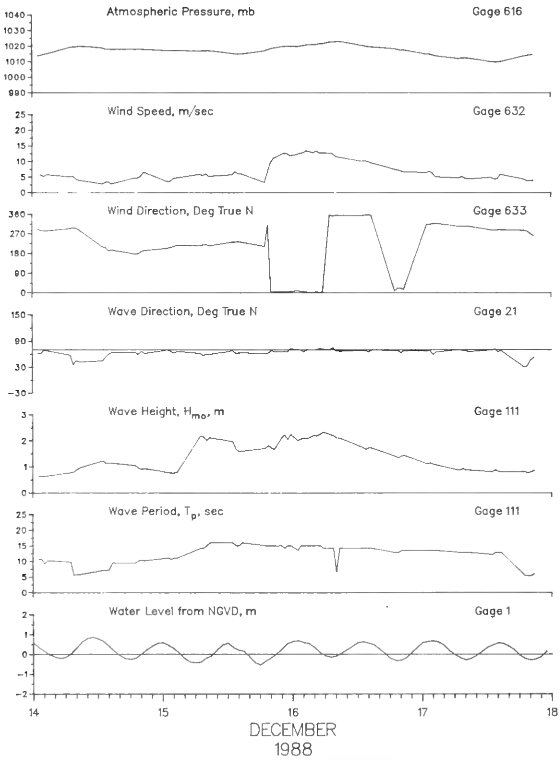


Figure 41. Data for 4 December 1988 storm

15-16 December 1988 (Figure 42)

80. A strong storm located well offshore followed a track parallel to the east coast and generated northerly winds that peaked in excess of 13 m/sec at 0242 EST on 16 December. At 0542 EST that same day, maximum H_{mo} (Gage 111) of 2.34 m (T_p = 14.22 sec) was recorded. Because the storm remained well offshore, the atmospheric pressure was only slightly affected. There was no precipitation.

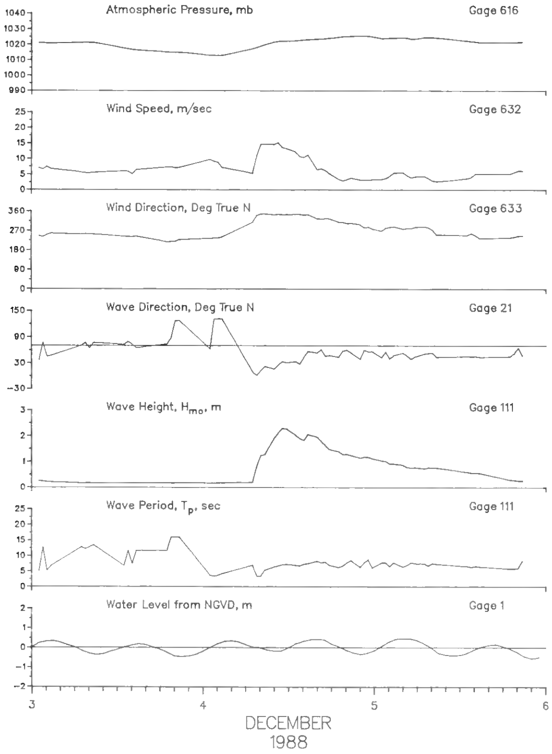


Figure 42. Data for 15-16 December 1988 storm

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APPENDIX A: SURVEY DATA

1. Contour diagrams constructed from the bathymetric survey data are presented in this appendix. The profile lines surveyed are identified on each diagram. Contours are in half meters referenced to National Geodetic Vertical Datum (NGVD). The distance offshore is referenced to the Field Research Facility (FRF) monumentation baseline behind the dune.

2. Change in FRF bathymetry diagrams constructed by contouring the difference between two contour diagrams are also presented with contour intervals of 0.25 m. Wide contour lines show areas of erosion. Other areas correspond to areas of accretion. Although these change diagrams are based on considerable interpolation of the original survey data, they do facilitate comparison of the contour diagrams.

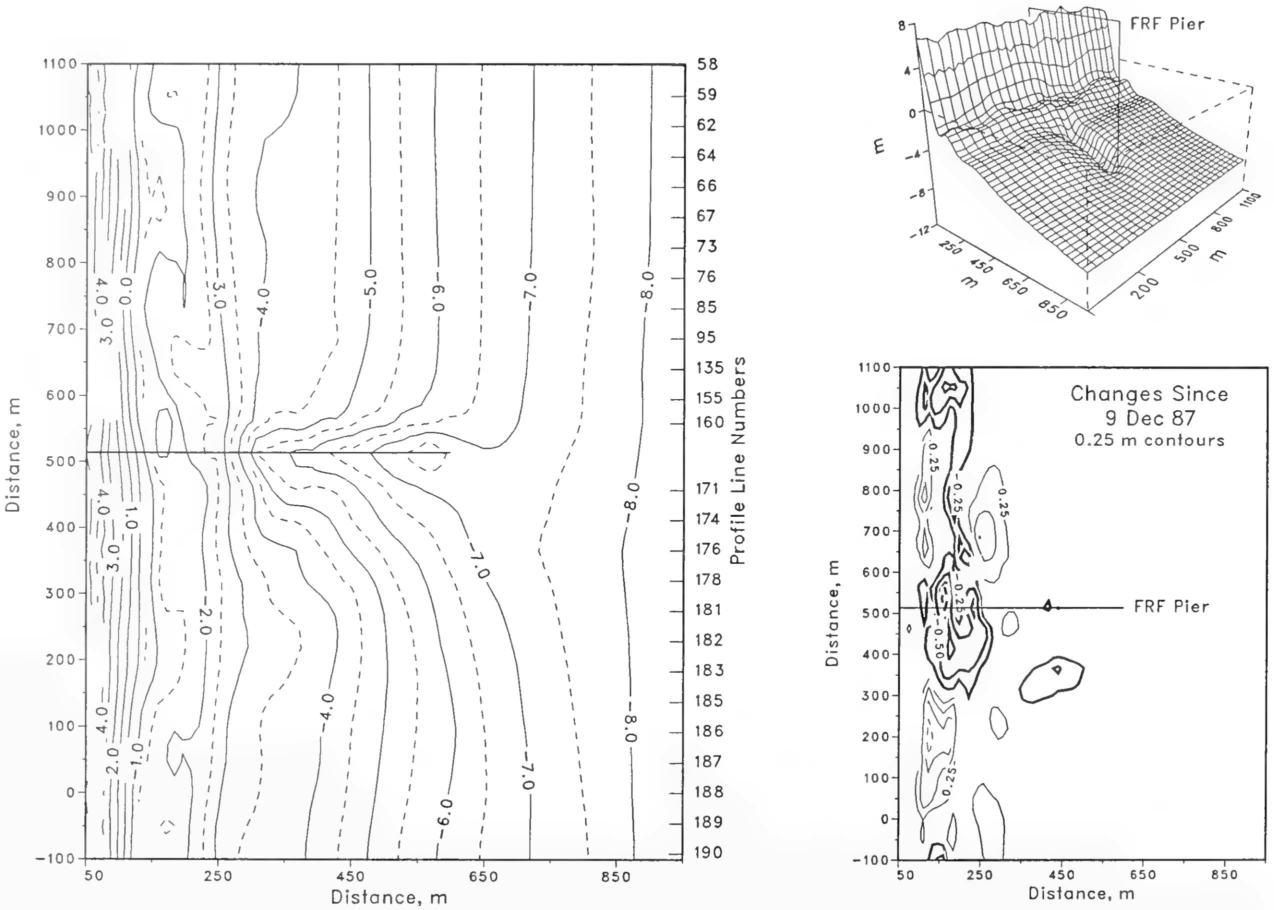


Figure A1. FRF Bathymetry 2 February 88 (depths relative to NGVD)

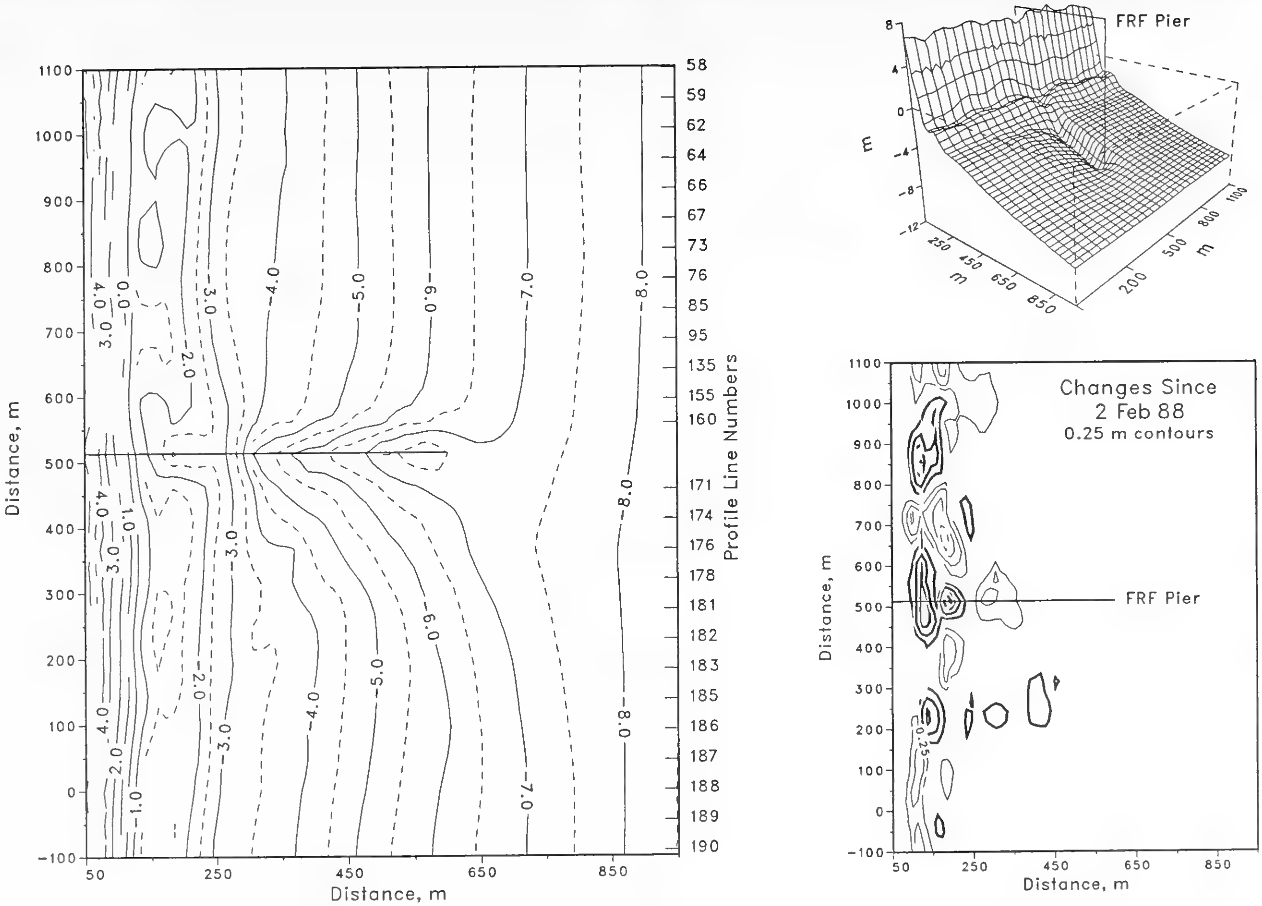


Figure A2. FRF Bathymetry 30 March 88 (depths relative to NGVD)

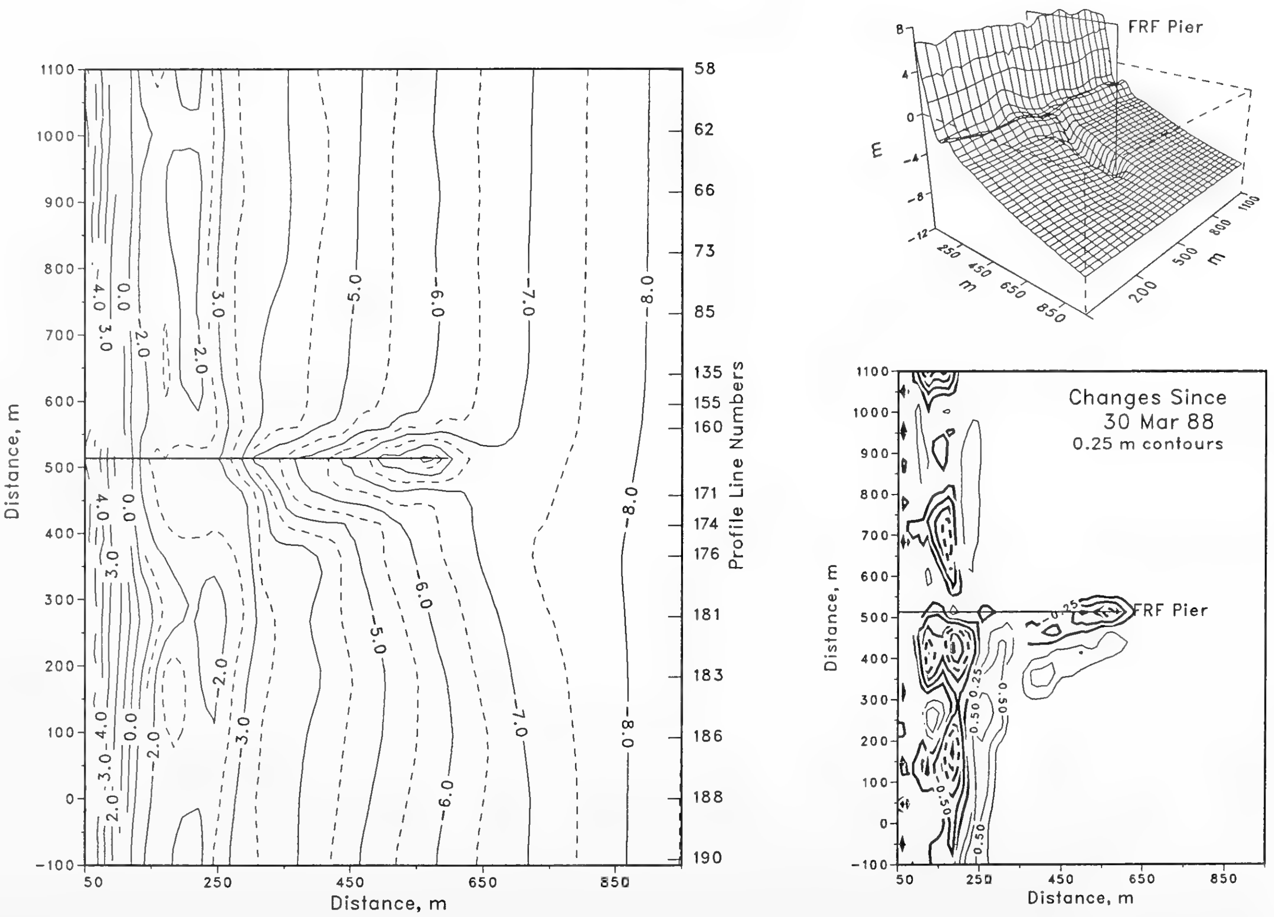


Figure A3. FRF Bathymetry 21 April 88 (depths relative to NGVD)

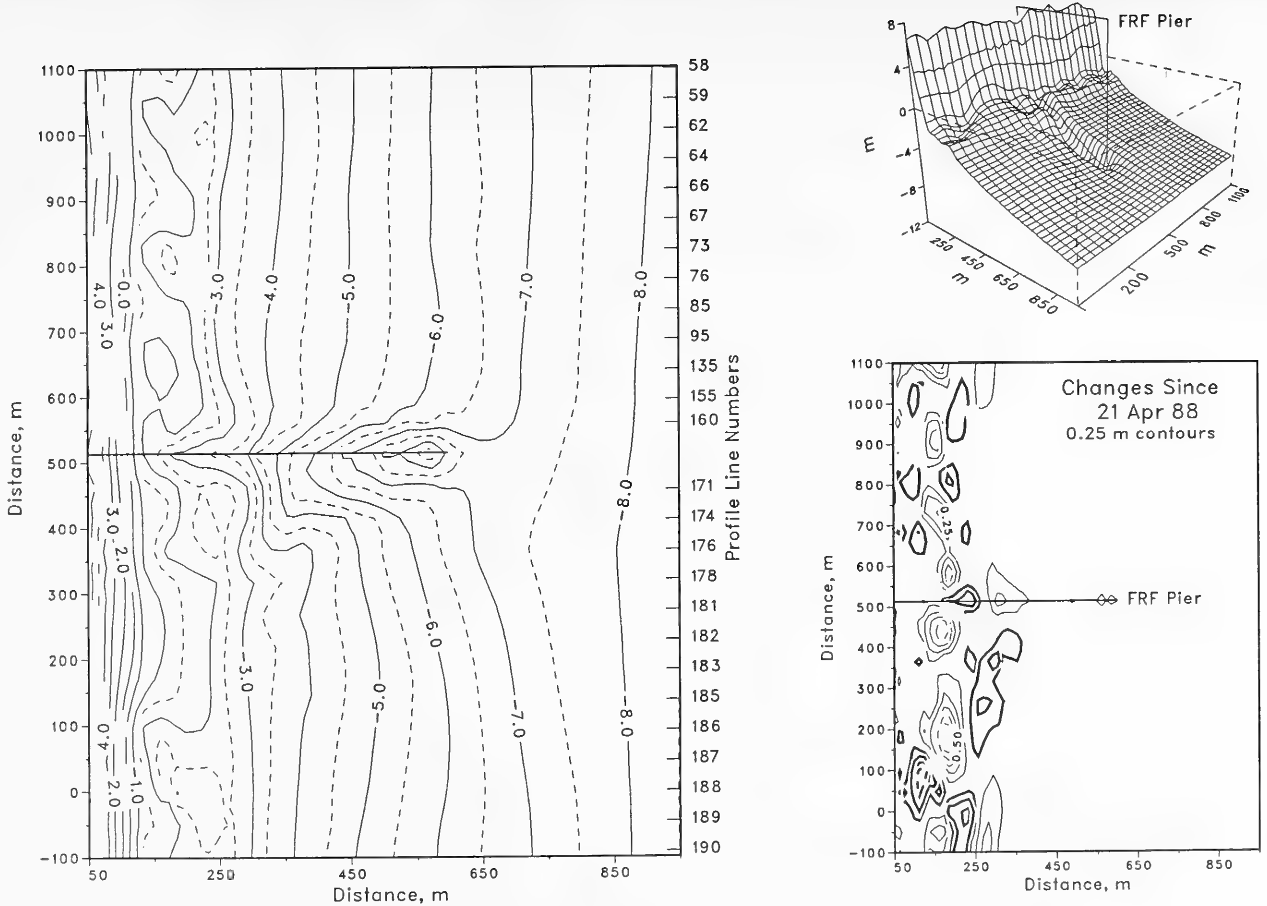


Figure A4. FRF Bathymetry 8 June 88 (depths relative to NGVD)

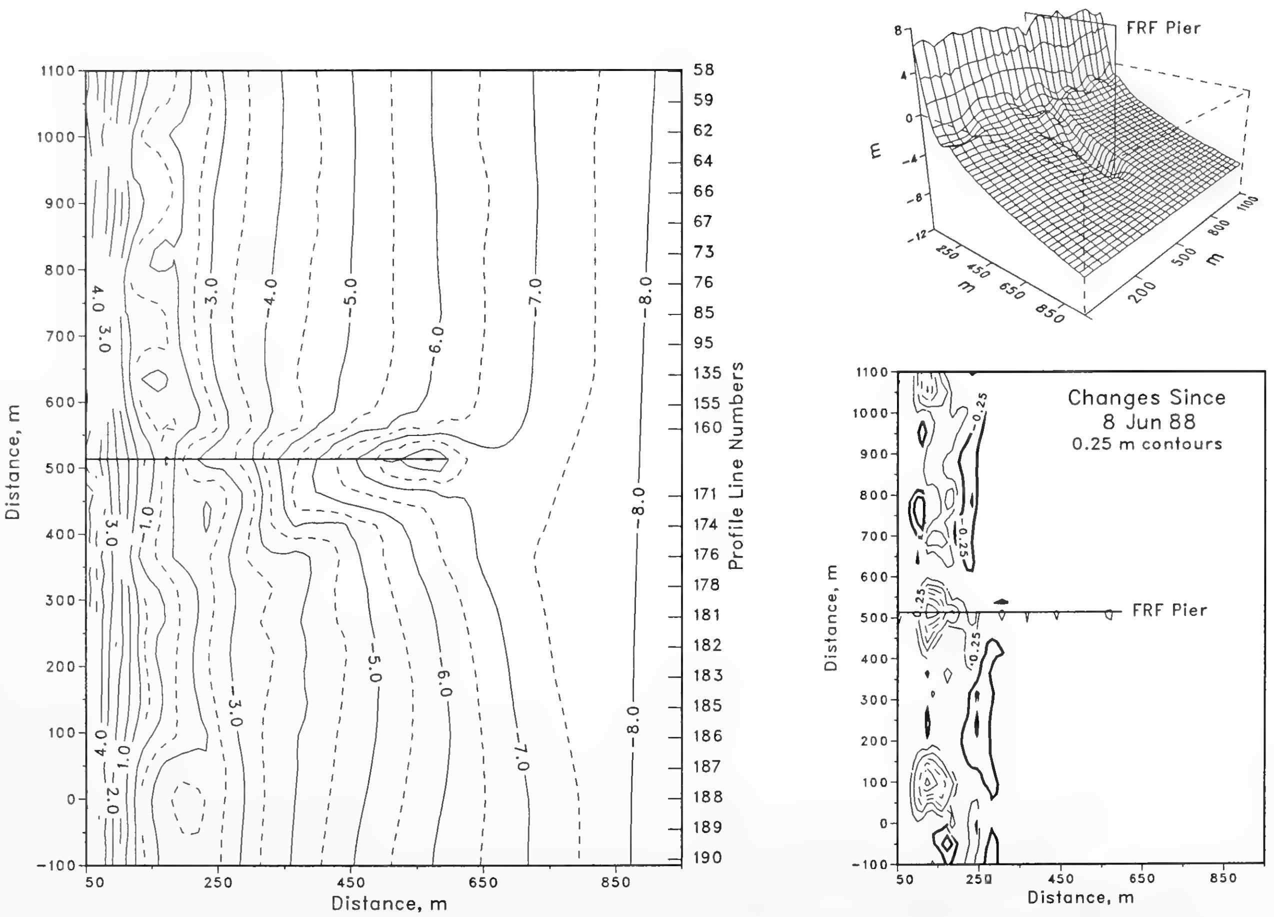


Figure A5. FRF Bathymetry 8 July 88 (depths relative to NGVD)

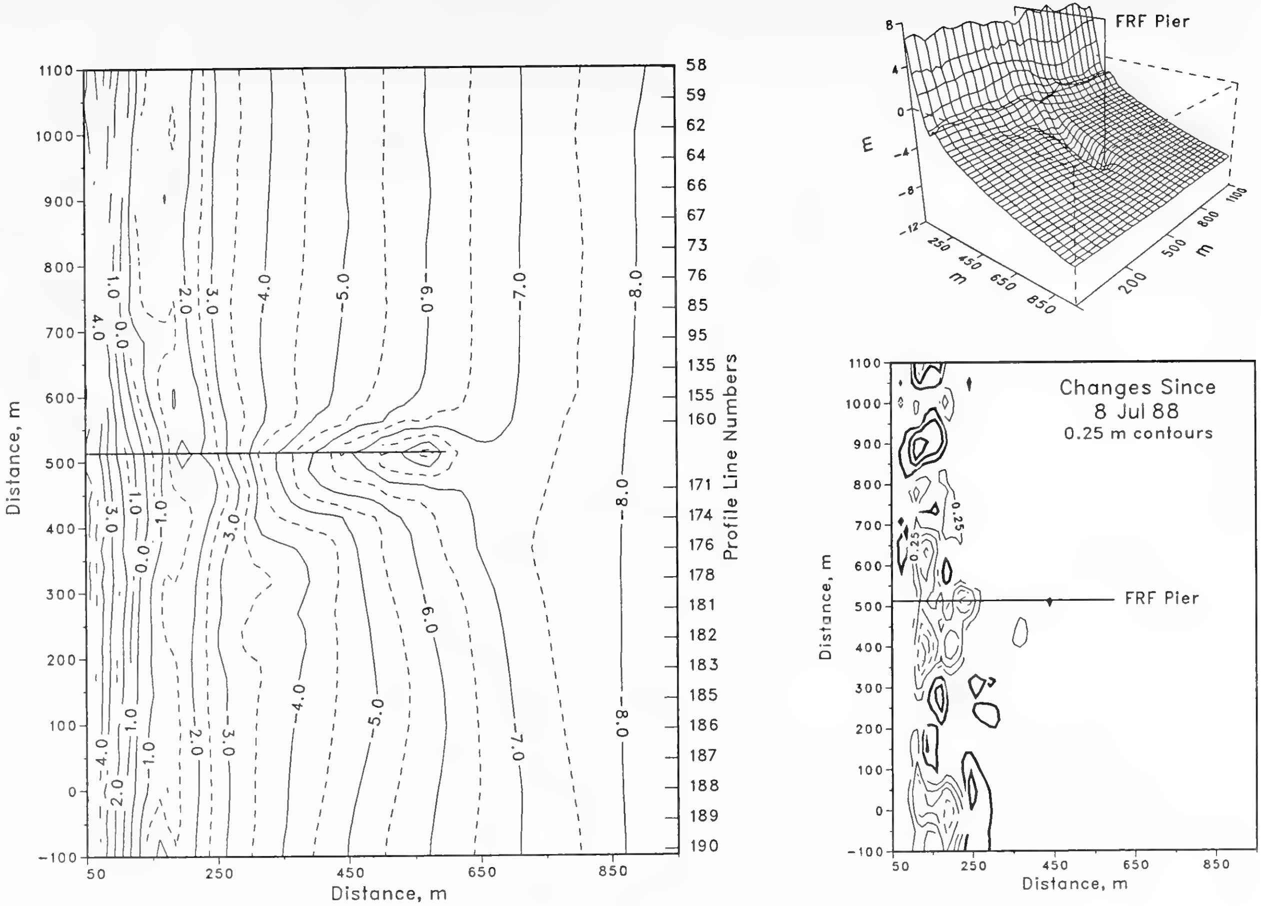


Figure A6. FRF Bathymetry 9 September 88 (depths relative to NGVD)

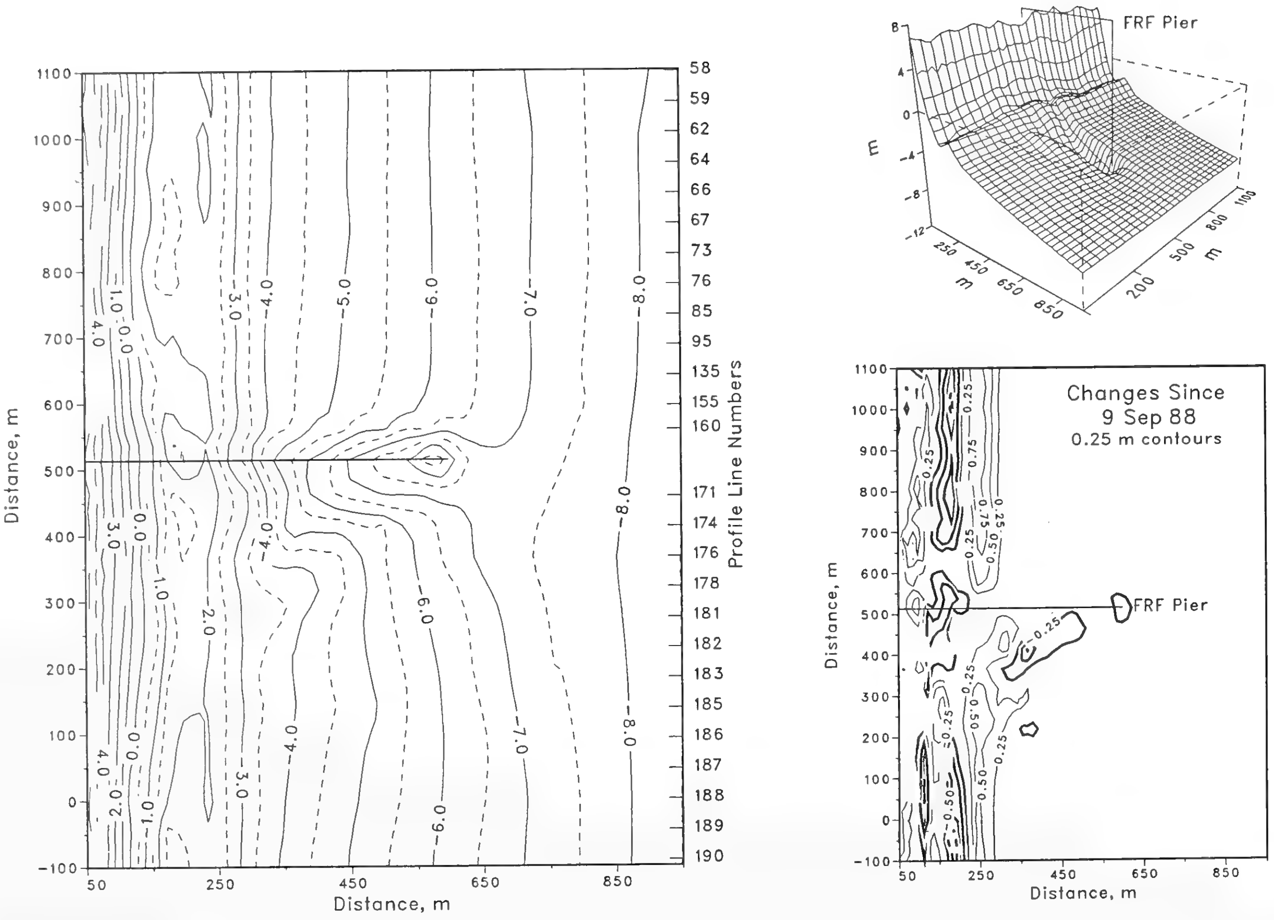


Figure A7. FRF Bathymetry 21 November 88 (depths relative to NGVD)

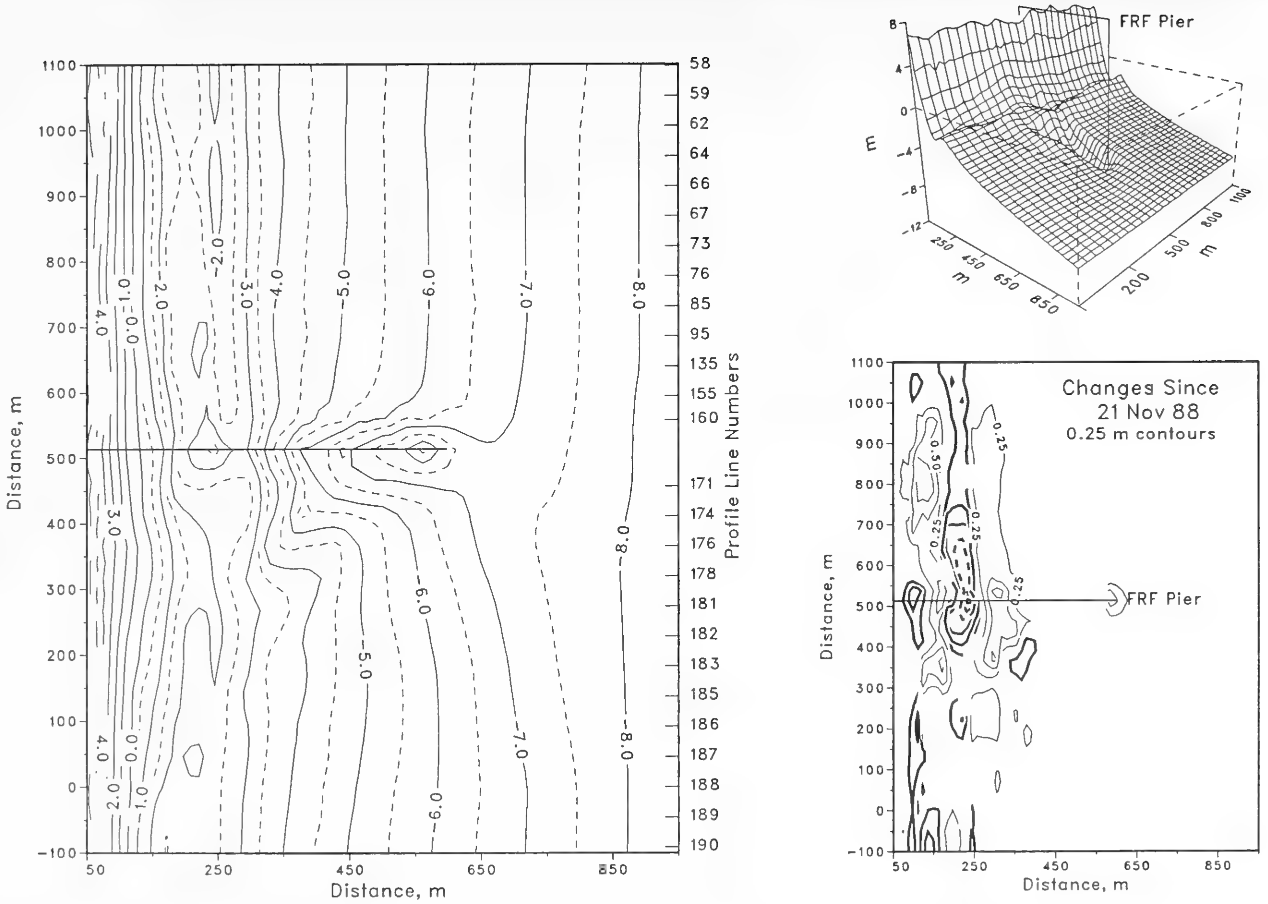


Figure A8. FRF Bathymetry 19 December 88 (depths relative to NGVD)

APPENDIX B: WAVE DATA FOR GAGE 630

1. Wave data summaries for Gage 630 are presented for 1988 and for 1980 through 1988 in the following forms:

Daily H_{mo} and T_p

2. Figure B1 displays the individual wave height and peak spectral wave period values along with the monthly mean values.

Joint Distributions of H_{mo} and T_p

3. Annual and monthly joint distributions tables are presented in Tables B1 and B2, and data for 1980 through 1988 are in Tables B3 and B4. Each table gives the frequency (in parts per 10,000) for which the wave height and peak period were within the specified intervals; these values can be converted to percent by dividing by 100. Marginal totals are also included. The row total gives the total number of observations out of 10,000 which fell within each specified peak period interval. The column total gives the number of observations out of 10,000 which fell within each specified wave height interval.

Cumulative Distributions of Wave Height

4. Annual and monthly wave height distributions for 1988 are plotted in cumulative form in Figures B2 and B3. Data for 1980 through 1988 are in Figure B4.

Peak Spectral Wave Period Distributions

5. Annual and monthly peak wave period, T_p, distribution histograms for 1988 are presented in Figures B5 and B6. Data for 1980 through 1988 are in Figure B7.

Persistence of Wave Heights

6. Table B5 shows the number of times in 1988 when the specified wave height was equaled or exceeded at least once during each day for the duration (consecutive days). Data for 1980 through 1988 are given in Table B6. An example is shown below:

Height	Consecutive Day(s) or Longer																		
m	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.5	18	15		14	13	12		11	10	9				8		7			
1.0	50	34	24	21	18	14	12	8	7	3			2						
1.5	41	19	8	6	2	1													
2.0	22	9	5	1															
2.5	10	5	2																
3.0	6	1																	
3.5		1																	
4.0	1																		

This example indicates that wave heights equaled or exceeded 1.0 m 50 times for at least 1 day; 34 times for at least 2 days; 24 times for at least 3 days, etc. Therefore, on 16 occasions the height equaled or exceeded 1.0 m for 1 day exactly (50 - 34 = 16); on 10 occasions for 2 days; on 3 occasions for 3 days, etc. Note that the height exceeded 1 m 50 times for 1 day or longer, while heights exceeded 0.5 m only 18 times for this same duration. This change in durations occurred because the longer durations of lower waves may be interspersed with shorter, but more frequent, intervals of higher waves. For example, one of the times that the wave heights exceeded 0.5 m for 16 days may have represented 3 times the height exceeded 1 m for shorter durations.

Spectra

7. Monthly spectra for the offshore Waverider buoy (Gage 630) are presented in Figure B8. The plots show "relative" energy density as a function of wave frequency. These figures summarize the large number of spectra for each month. The figures emphasize the higher energy density associated with storms as well as the general shifts in energy density to different frequencies. As used here, "relative" indicates the spectra have been smoothed by the three-dimensional surface drawing routine. Consequently, extremely high- and low-energy density values are modified to produce a smooth

surface. The figures are not intended for quantitative measurements; however, they do provide the energy density as a function of frequency relative to the other spectra for the month.

8. Monthly and annual wave statistics for Gage 630 for 1988 and for 1980 through 1988 are presented in Table B7.

9. Figure B9 plots monthly time histories of wave height and period.

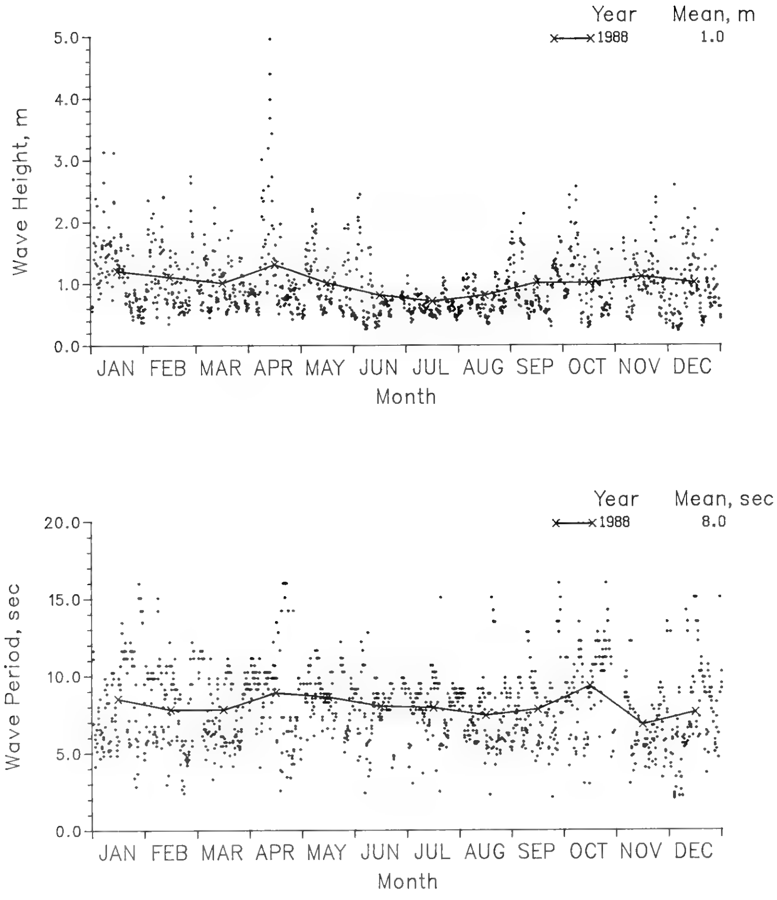


Figure B1. 1988 daily wave height and period values with monthly means for Gage 630

Table B1

Annual Joint Distribution of H_{mo} versus T_p

Annual 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	88	22	22	103	22	96	301	301	103	44	103	.	1205
0.50 - 0.99	66	147	301	662	551	610	1051	904	662	118	191	.	5263
1.00 - 1.49	.	.	184	515	456	221	206	199	272	29	118	.	2200
1.50 - 1.99	.	.	22	265	199	74	110	74	154	22	37	.	957
2.00 - 2.49	.	.	.	29	81	44	51	15	22	.	7	.	249
2.50 - 2.99	.	.	.	7	22	7	.	15	.	.	7	.	58
3.00 - 3.49	.	.	.	.	.	22	7	7	.	.	.	.	36
3.50 - 3.99	.	.	.	.	.	.	15	.	.	.	.	.	15
4.00 - 4.49	.	.	.	.	.	.	7	.	.	.	.	.	7
4.50 - 4.99	.	.	.	.	.	.	.	7	.	.	.	.	7
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	154	169	529	1581	1331	1074	1748	1522	1213	213	463	0	

Table B2

Monthly Joint Distribution of H_{mo} versus T_p

January 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	81	.	.	81	.	161	242	242	.	807
0.50 - 0.99	81	161	242	403	403	161	161	242	887	242	242	.	3225
1.00 - 1.49	.	.	242	484	565	81	323	565	806	.	81	.	3147
1.50 - 1.99	.	.	81	1048	161	161	81	242	161	81	161	.	2177
2.00 - 2.49	.	.	.	.	161	161	.	81	.	.	.	.	403
2.50 - 2.99	.	.	.	.	81	.	.	.	.	.	.	.	81
3.00 - 3.49	.	.	.	.	.	81	81	.	.	.	.	.	162
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	81	161	565	2016	1371	645	727	1130	2015	565	726	0	

February 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	86	.	.	.	.	86	86	172	.	430
0.50 - 0.99	345	172	603	948	172	86	690	1121	776	.	.	.	4913
1.00 - 1.49	.	.	259	517	259	259	172	259	690	.	.	.	2415
1.50 - 1.99	.	.	.	172	517	172	259	86	259	.	.	.	1465
2.00 - 2.49	.	.	.	172	172	.	86	86	.	.	86	.	602
2.50 - 2.99	.	.	.	86	.	.	.	86	.	.	.	.	172
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	345	172	862	1981	1120	517	1207	1638	1811	86	258	0	

March 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	.	.	.	83	.	.	.	.	.	83
0.50 - 0.99	.	83	83	826	1074	413	579	1736	1488	.	.	.	6282
1.00 - 1.49	.	.	331	661	661	413	331	165	331	.	.	.	2893
1.50 - 1.99	.	.	83	331	165	83	.	.	.	.	.	.	662
2.00 - 2.49	.	.	.	83	.	.	.	.	.	.	.	.	83
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	83	497	1901	1900	909	993	1901	1819	0	0	0	

(Continued)

(Sheet 1 of 4)

Table B2 (Continued)

April 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	.	.	.	.	172	.	86	.	.	258
0.50 - 0.99	86	345	603	345	690	603	86	1293	1034	345	776	.	6206
1.00 - 1.49	.	.	.	172	259	259	86	517	172	.	.	.	1465
1.50 - 1.99	.	.	.	172	.	86	.	172	345	.	.	.	775
2.00 - 2.49	.	.	.	.	.	.	172	.	259	.	.	.	431
2.50 - 2.99	.	.	.	.	86	.	.	86	.	.	86	.	258
3.00 - 3.49	.	.	.	.	.	172	.	86	.	.	.	.	258
3.50 - 3.99	.	.	.	.	.	.	172	.	.	.	.	.	172
4.00 - 4.49	.	.	.	.	.	.	86	.	.	.	.	.	86
4.50 - 4.99	.	.	.	.	.	.	.	86	.	.	.	.	86
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	86	345	603	689	1035	1120	602	2412	1810	431	862	0	

May 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	90	.	.	450	270	.	.	.	.	810
0.50 - 0.99	.	.	.	270	360	631	1802	1261	721	.	90	.	5135
1.00 - 1.49	.	.	.	270	270	450	721	180	541	.	.	.	2432
1.50 - 1.99	.	.	.	.	180	180	360	180	541	.	.	.	1441
2.00 - 2.49	.	.	.	.	90	90	.	.	.	.	.	.	180
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	0	0	0	630	900	1351	3333	1891	1803	0	90	0	

June 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	99	99	99	297	99	693	891	792	.	.	198	.	3267
0.50 - 0.99	.	198	495	.	.	990	1980	990	297	.	.	.	4950
1.00 - 1.49	.	.	99	.	396	99	.	.	99	.	.	.	693
1.50 - 1.99	.	.	99	99	99	.	.	.	198	.	99	.	594
2.00 - 2.49	.	.	.	.	99	99	297	.	.	.	.	.	495
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	99	297	792	396	693	1881	3168	1782	594	0	297	0	

(Continued)

(Sheet 2 of 4)

Table B2 (Continued)

July 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	83	.	165	909	744	248	.	.	.	2149
0.50 - 0.99	83	248	83	826	1074	1405	2562	992	165	.	83	.	7521
1.00 - 1.49	.	.	.	83	248	.	.	.	.	.	.	.	331
1.50 - 1.99	.	.	.	.	.	.	.	.	.	.	.	.	0
2.00 - 2.49	.	.	.	.	.	.	.	.	.	.	.	.	0
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	83	248	83	992	1322	1570	3471	1736	413	0	83	0	

August 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	84	.	84	336	84	.	336	84	.	.	.	.	1008
0.50 - 0.99	.	.	252	1092	1092	1261	2101	756	.	336	84	.	6974
1.00 - 1.49	.	.	84	1008	588	.	168	84	.	.	.	.	1932
1.50 - 1.99	.	.	.	84	.	.	.	.	.	.	.	.	84
2.00 - 2.49	.	.	.	.	.	.	.	.	.	.	.	.	0
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	84	0	420	2520	1764	1261	2605	924	0	336	84	0	

September 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	90	.	.	.	90	.	90	360	90	.	.	.	720
0.50 - 0.99	.	.	270	1171	450	991	721	1081	180	.	360	.	5224
1.00 - 1.49	.	.	90	631	721	360	270	.	90	270	360	.	2792
1.50 - 1.99	.	.	.	450	450	90	180	.	.	.	.	.	1170
2.00 - 2.49	.	.	.	.	90	.	.	.	.	.	.	.	90
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	90	0	360	2252	1801	1441	1261	1441	360	270	720	0	

(Continued)

(Sheet 3 of 4)

October 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	93	.	.	.	.	93	278	278	556	.	278	.	1576
0.50 - 0.99	93	.	93	370	185	.	648	648	1759	278	278	.	4352
1.00 - 1.49	.	.	278	648	93	.	93	278	278	.	833	.	2501
1.50 - 1.99	.	.	.	185	185	.	278	93	370	93	.	.	1204
2.00 - 2.49	.	.	.	.	93	93	93	.	.	.	.	.	279
2.50 - 2.99	.	.	.	.	93	.	.	.	.	.	.	.	93
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	186	0	371	1203	649	186	1390	1297	2963	371	1389	0	

November 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	.	.	.	.	319	319	213	.	106	319	.	1276
0.50 - 0.99	106	319	532	1064	532	532	638	106	.	.	.	.	3829
1.00 - 1.49	.	.	851	1383	532	532	213	213	106	.	.	.	3830
1.50 - 1.99	.	.	.	106	213	106	213	106	.	.	.	.	744
2.00 - 2.49	.	.	.	106	106	106	.	.	.	.	.	.	318
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	106	319	1383	2659	1383	1595	1383	638	106	106	319	0	

December 1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	678	169	85	254	.	.	254	763	85	.	85	.	2373
0.50 - 0.99	.	254	424	593	424	254	678	508	508	169	339	.	4151
1.00 - 1.49	.	.	85	424	847	254	85	85	85	85	169	.	2119
1.50 - 1.99	.	.	.	424	424	.	.	.	.	85	169	.	1102
2.00 - 2.49	.	.	.	.	169	.	.	.	.	.	.	.	169
2.50 - 2.99	.	.	.	.	.	85	.	.	.	.	.	.	85
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	678	423	594	1695	1864	593	1017	1356	678	339	762	0	

(Sheet 4 of 4)

Table B3

Annual Joint Distribution of H_{mo} versus T_p (All Years)

Annual 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec)												Total
	2.0- 2.9	3.0- 3.9	4.0- 4.9	5.0- 5.9	6.0- 6.9	7.0- 7.9	8.0- 8.9	9.0- 9.9	10.0- 11.9	12.0- 13.9	14.0- 15.9	16.0- Longer	
0.00 - 0.49	28	18	28	62	94	115	328	281	200	76	134	4	1368
0.50 - 0.99	39	128	254	499	572	515	860	717	812	151	213	15	4775
1.00 - 1.49	.	10	134	402	451	264	246	200	360	39	132	4	2242
1.50 - 1.99	.	.	13	156	256	109	79	70	139	35	77	4	938
2.00 - 2.49	.	.	2	26	78	74	49	41	70	29	41	2	412
2.50 - 2.99	.	.	.	1	9	32	17	16	38	11	23	.	147
3.00 - 3.49	.	.	.	.	1	9	15	14	17	4	9	.	69
3.50 - 3.99	.	.	.	.	.	1	5	7	10	4	4	.	31
4.00 - 4.49	.	.	.	.	.	.	2	2	7	1	2	.	14
4.50 - 4.99	.	.	.	.	.	.	.	1	3	.	.	.	4
5.00 - Greater	.	.	.	.	.	.	1	.	.	2	1	.	4
Total	67	156	431	1146	1461	1119	1602	1349	1656	352	636	29	

Table B4

Monthly Joint Distribution of H_{mo} versus T_p (All Years)

January 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec)												Total
	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	
0.00 - 0.49	105	11	.	105	84	32	168	84	221	63	105	.	978
0.50 - 0.99	74	232	253	368	389	347	305	495	874	116	253	.	3706
1.00 - 1.49	.	21	168	505	558	221	168	179	589	.	74	11	2494
1.50 - 1.99	.	.	32	379	463	232	95	116	242	21	63	.	1643
2.00 - 2.49	.	.	.	32	189	221	95	32	126	42	32	11	780
2.50 - 2.99	.	.	.	.	21	84	53	21	42	21	53	.	295
3.00 - 3.49	.	.	.	.	.	11	32	11	32	.	.	.	86
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	11	.	.	.	11
4.50 - 4.99	.	.	.	.	.	.	.	.	11	.	.	.	11
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	179	264	453	1389	1704	1148	916	938	2148	263	580	22	

February 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec)												Total
	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	
0.00 - 0.49	.	.	.	22	33	22	88	.	44	33	133	.	375
0.50 - 0.99	66	77	155	453	453	243	541	685	1116	22	144	11	3966
1.00 - 1.49	.	11	110	619	652	232	298	354	608	88	221	.	3193
1.50 - 1.99	.	.	11	188	365	199	110	99	221	66	110	.	1369
2.00 - 2.49	.	.	.	99	122	22	44	88	99	55	110	.	639
2.50 - 2.99	.	.	.	11	11	33	.	11	122	22	66	.	276
3.00 - 3.49	.	.	.	.	.	11	.	22	33	11	22	.	99
3.50 - 3.99	.	.	.	.	.	.	.	11	11	.	.	.	22
4.00 - 4.49	.	.	.	.	.	.	.	11	33	.	.	.	44
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	11	.	.	.	.	.	11
Total	66	88	276	1392	1636	762	1092	1281	2287	297	806	11	

March 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec)												Total
	2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	
0.00 - 0.49	10	.	.	10	50	50	80	40	120	60	60	.	480
0.50 - 0.99	10	90	190	421	511	421	521	772	872	150	180	.	4138
1.00 - 1.49	.	10	210	411	541	341	281	301	711	60	331	.	3197
1.50 - 1.99	.	.	10	240	230	100	80	100	251	90	140	.	1241
2.00 - 2.49	.	.	.	20	50	30	70	50	160	40	110	.	530
2.50 - 2.99	.	.	.	.	20	10	10	10	60	20	50	.	180
3.00 - 3.49	.	.	.	.	10	.	10	20	50	10	10	.	110
3.50 - 3.99	.	.	.	.	.	.	.	20	20	.	10	.	50
4.00 - 4.49	.	.	.	.	.	.	10	10	10	.	20	.	50
4.50 - 4.99	.	.	.	.	.	.	.	.	20	.	.	.	20
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	20	100	410	1102	1412	952	1062	1323	2274	430	911	0	

(Continued)

(Sheet 1 of 4)

Table B4 (Continued)

April 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	.	10	21	21	31	21	308	226	185	103	103	.	1029
0.50 - 0.99	92	195	267	390	503	513	677	697	1128	287	421	.	5170
1.00 - 1.49	.	10	103	226	369	318	328	287	369	62	154	.	2226
1.50 - 1.99	.	.	.	144	123	92	92	113	215	31	113	.	923
2.00 - 2.49	.	.	.	41	31	10	51	62	62	31	10	.	298
2.50 - 2.99	.	.	.	.	10	21	31	21	41	31	21	.	176
3.00 - 3.49	.	.	.	.	.	31	21	31	31	.	.	.	114
3.50 - 3.99	.	.	.	.	.	10	41	.	.	.	.	.	51
4.00 - 4.49	.	.	.	.	.	.	10	.	.	.	.	.	10
4.50 - 4.99	.	.	.	.	.	.	.	10	.	.	.	.	10
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	92	215	391	822	1067	1016	1559	1447	2031	545	822	0	

May 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	10	20	31	92	132	163	448	254	153	20	61	.	1384
0.50 - 0.99	20	153	326	621	560	712	1312	1099	712	31	163	.	5709
1.00 - 1.49	.	.	92	234	336	224	448	193	336	10	92	.	1965
1.50 - 1.99	.	.	10	51	92	41	132	81	122	31	71	.	631
2.00 - 2.49	.	.	.	20	20	61	.	41	10	31	31	.	214
2.50 - 2.99	.	.	.	.	10	10	10	10	10	20	10	.	80
3.00 - 3.49	.	.	.	.	.	.	.	.	.	10	10	.	20
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	30	173	459	1018	1150	1211	2350	1678	1343	153	438	0	

June 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	32	43	65	119	227	378	636	583	205	43	32	.	2363
0.50 - 0.99	54	237	378	658	658	734	1650	895	572	173	32	.	6041
1.00 - 1.49	.	.	76	205	227	194	194	108	108	.	54	.	1166
1.50 - 1.99	.	.	22	54	76	65	22	11	76	.	11	.	337
2.00 - 2.49	.	.	.	.	22	22	43	11	.	.	.	.	98
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	86	280	541	1036	1210	1393	2545	1608	961	216	129	0	

(Continued)

(Sheet 2 of 4)

Table B4 (Continued)

July 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	11	21	53	105	243	285	1108	791	327	127	253	21	3345
0.50 - 0.99	42	137	316	643	802	781	1487	918	411	222	74	63	5896
1.00 - 1.49	.	21	53	169	190	84	53	42	.	.	.	.	612
1.50 - 1.99	.	.	.	53	11	21	32	.	.	.	.	.	117
2.00 - 2.49	.	.	.	11	.	.	11	.	.	.	.	.	22
2.50 - 2.99	.	.	.	.	.	.	.	.	.	.	.	.	0
3.00 - 3.49	.	.	.	.	.	.	.	.	.	.	.	.	0
3.50 - 3.99	.	.	.	.	.	.	.	.	.	.	.	.	0
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	53	179	422	981	1246	1171	2691	1751	738	349	327	84	

August 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	32	32	74	137	179	211	474	495	369	74	105	.	2182
0.50 - 0.99	32	95	242	643	832	769	1412	790	537	190	274	.	5816
1.00 - 1.49	.	11	148	390	285	232	158	105	63	11	.	.	1403
1.50 - 1.99	.	.	.	63	137	74	32	21	21	.	32	.	380
2.00 - 2.49	.	.	.	21	21	11	21	.	42	.	11	.	127
2.50 - 2.99	.	.	.	.	11	.	21	.	11	.	11	.	54
3.00 - 3.49	.	.	.	.	.	11	11	.	11	.	.	.	33
3.50 - 3.99	.	.	.	.	.	.	.	11	.	.	.	.	11
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	64	138	464	1254	1465	1308	2129	1422	1054	275	433	0	

September 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	10	10	10	31	31	21	94	333	271	125	104	10	1050
0.50 - 0.99	.	52	188	417	583	521	813	802	1031	146	250	.	4803
1.00 - 1.49	.	10	83	438	604	354	448	219	354	83	177	10	2780
1.50 - 1.99	.	.	10	115	302	125	83	115	52	10	73	.	885
2.00 - 2.49	.	.	.	31	83	42	21	31	73	31	21	.	333
2.50 - 2.99	.	.	.	.	.	31	21	10	.	.	.	.	62
3.00 - 3.49	.	.	.	.	.	.	.	10	10	10	10	.	40
3.50 - 3.99	.	.	.	.	.	.	.	.	10	10	10	.	30
4.00 - 4.49	.	.	.	.	.	.	.	.	.	.	.	.	0
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	10	.	.	10
Total	10	72	291	1032	1603	1094	1480	1520	1801	425	645	20	

(Continued)

(Sheet 3 of 4)

Table B4 (Concluded)

October 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	29	.	.	.	48	67	202	164	260	38	144	.	952
0.50 - 0.99	10	38	144	337	404	375	674	481	991	173	318	10	3955
1.00 - 1.49	.	.	164	597	337	212	135	241	452	87	231	.	2456
1.50 - 1.99	.	.	29	192	423	77	77	67	202	96	212	38	1413
2.00 - 2.49	.	.	.	10	115	192	58	77	144	48	87	10	741
2.50 - 2.99	.	.	.	.	19	125	38	58	48	10	38	.	336
3.00 - 3.49	.	.	.	.	.	38	10	.	10	.	29	.	87
3.50 - 3.99	.	.	.	.	.	.	.	19	.	19	.	.	38
4.00 - 4.49	.	.	.	.	.	.	.	.	19	.	.	.	19
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	39	38	337	1136	1346	1086	1194	1107	2126	471	1059	58	

November 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	12	35	35	23	58	116	186	174	93	70	197	.	999
0.50 - 0.99	35	81	372	569	581	511	476	453	569	151	139	58	3995
1.00 - 1.49	.	23	267	569	720	453	232	244	325	23	81	35	2972
1.50 - 1.99	.	.	23	209	348	197	139	70	128	58	12	12	1196
2.00 - 2.49	.	.	.	35	81	139	151	46	23	23	12	.	510
2.50 - 2.99	.	.	.	.	.	23	12	23	58	.	12	.	128
3.00 - 3.49	.	.	.	.	.	.	23	58	.	12	12	.	105
3.50 - 3.99	.	.	.	.	.	.	.	.	46	23	12	.	81
4.00 - 4.49	.	.	.	.	.	.	.	.	.	12	.	.	12
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	.	.	.	0
Total	47	139	697	1405	1788	1439	1219	1068	1242	372	477	105	

December 1980-1988, Gage 630
Percent Occurrence(X100) of Height and Period

Height(m)	Period(sec) 2.0-2.9	3.0-3.9	4.0-4.9	5.0-5.9	6.0-6.9	7.0-7.9	8.0-8.9	9.0-9.9	10.0-11.9	12.0-13.9	14.0-15.9	16.0-Longer	Total
0.00 - 0.49	90	34	56	79	11	23	135	237	135	158	327	11	1296
0.50 - 0.99	34	158	237	496	609	237	417	485	891	147	293	45	4049
1.00 - 1.49	.	.	147	474	643	327	203	124	383	34	147	.	2482
1.50 - 1.99	.	.	11	180	519	101	56	45	124	11	68	.	1115
2.00 - 2.49	.	.	23	.	214	135	34	56	90	45	68	.	665
2.50 - 2.99	.	.	.	.	.	34	.	23	68	.	11	.	136
3.00 - 3.49	.	.	.	.	.	.	79	23	23	.	11	.	136
3.50 - 3.99	.	.	.	.	.	.	23	23	34	.	11	.	91
4.00 - 4.49	.	.	.	.	.	.	.	.	11	.	.	.	11
4.50 - 4.99	.	.	.	.	.	.	.	.	.	.	.	.	0
5.00 - Greater	.	.	.	.	.	.	.	.	.	11	11	.	22
Total	124	192	474	1229	1996	857	947	1016	1759	406	947	56	

(Sheet 4 of 4)

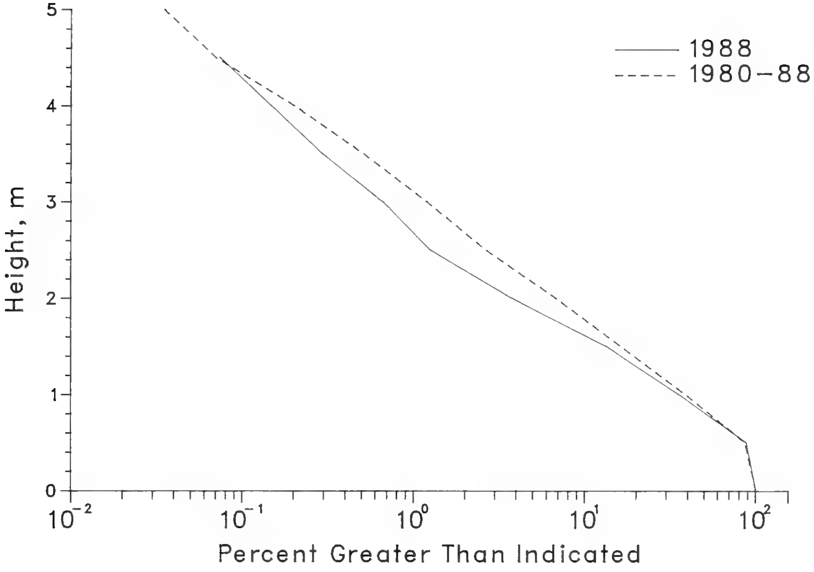


Figure B2. Annual cumulative wave height distributions for Gage 630

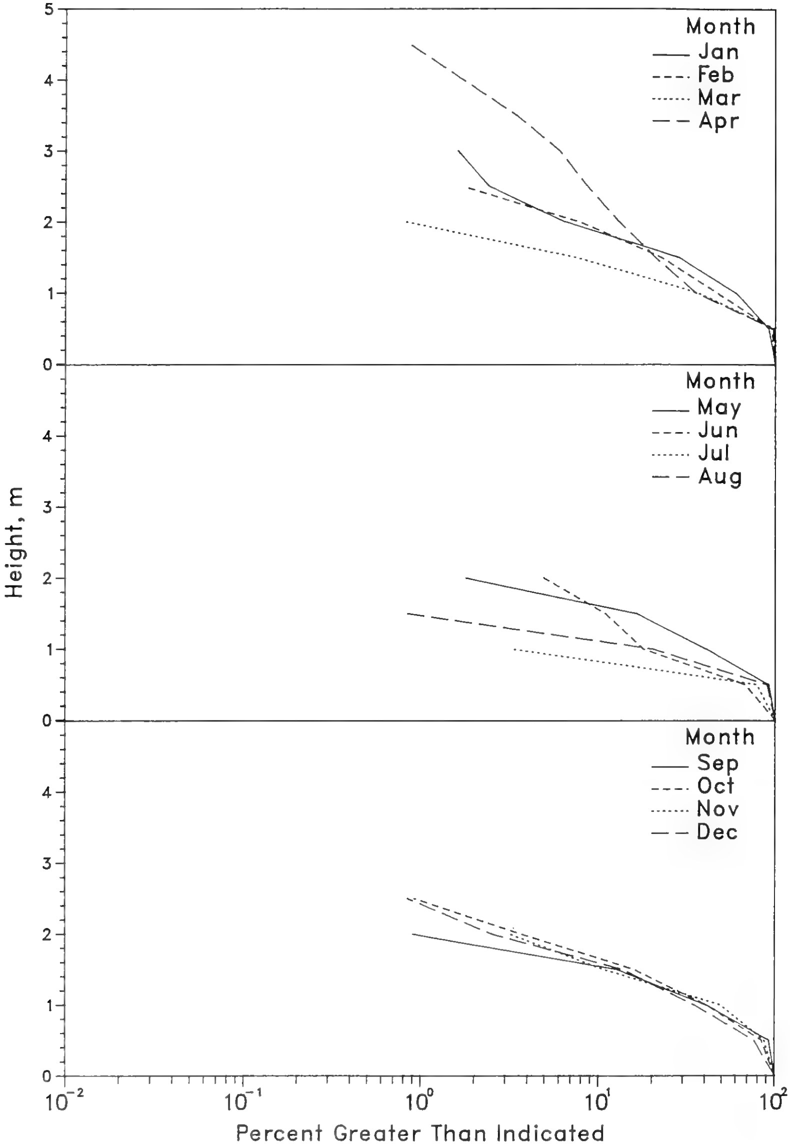


Figure B3. 1988 monthly wave height distributions for Gage 630

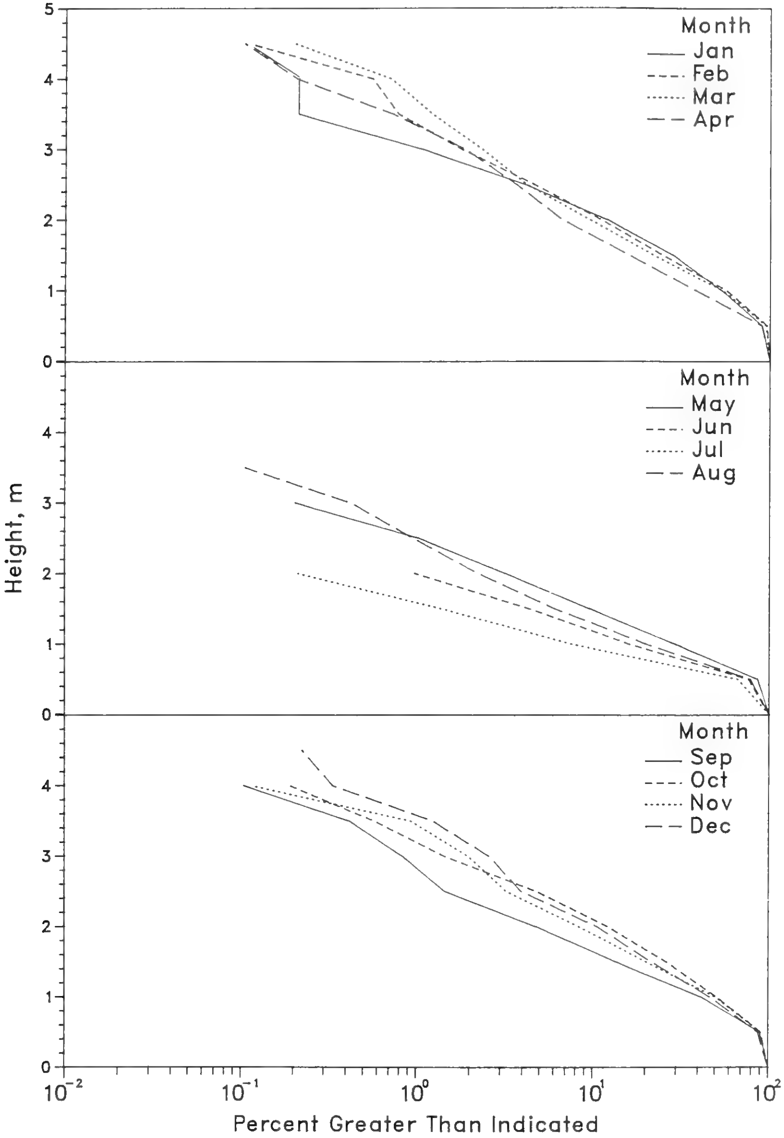


Figure B4. 1980-1988 monthly wave height distributions for Gage 630

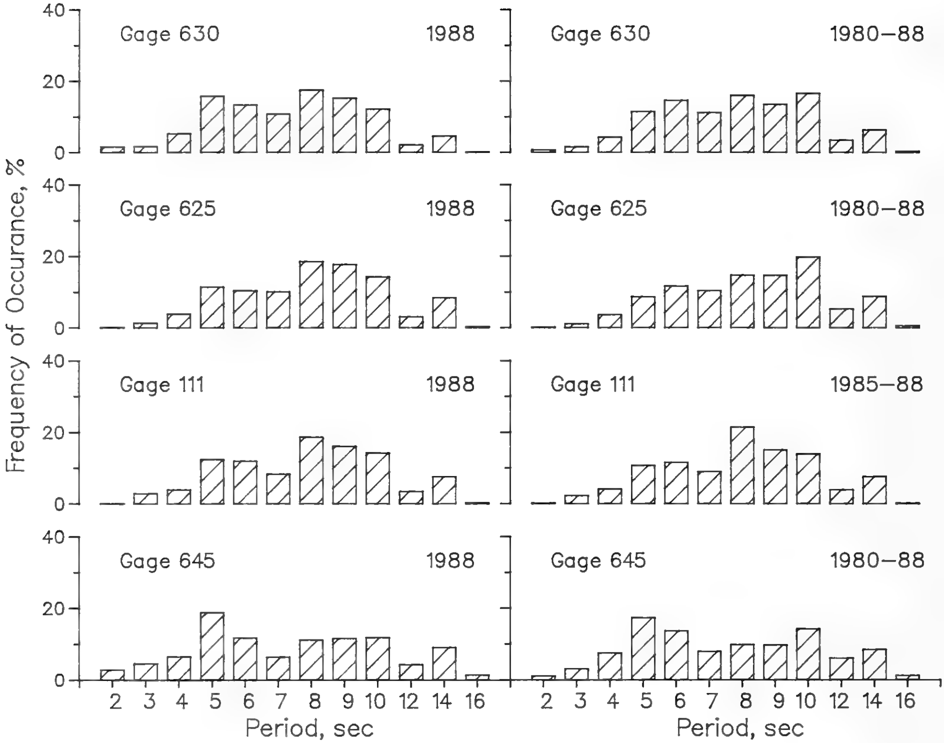


Figure B5. Annual wave period distributions for all gages

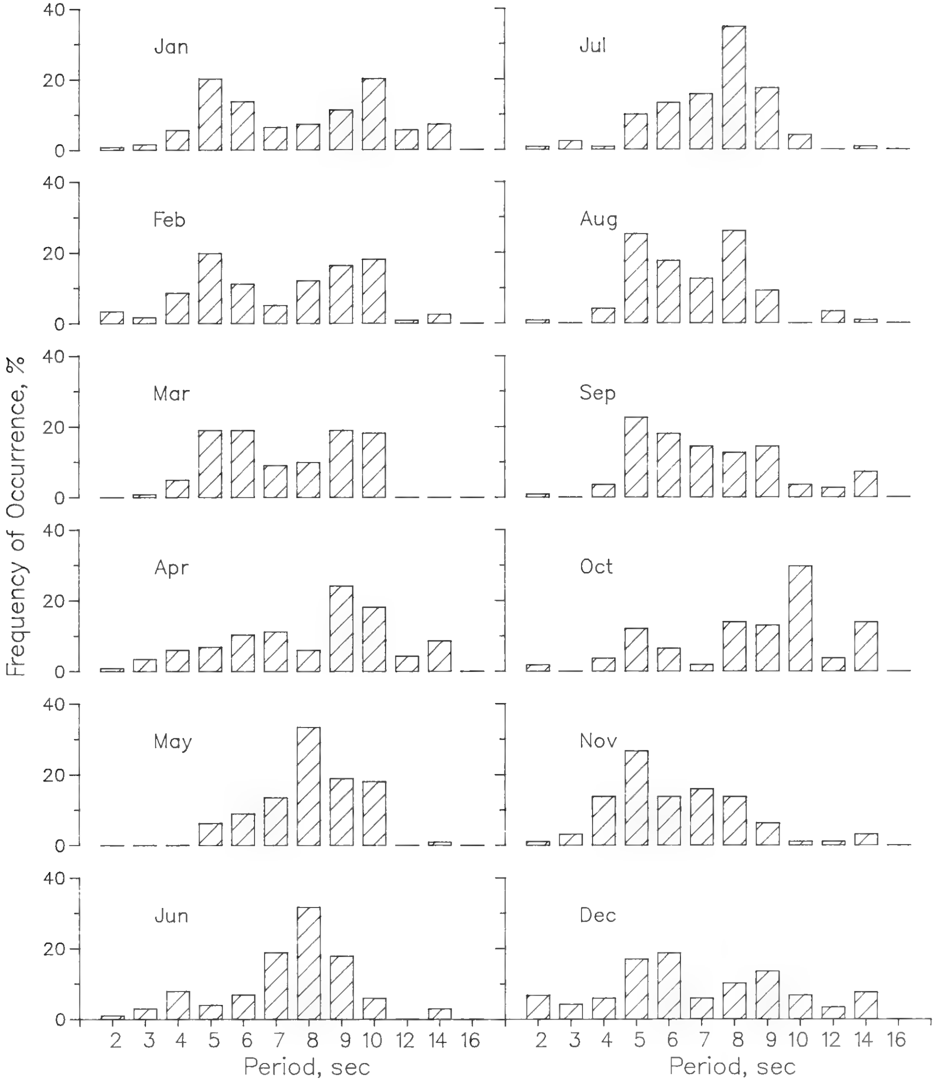


Figure B6. 1988 monthly wave period distributions for Gage 630

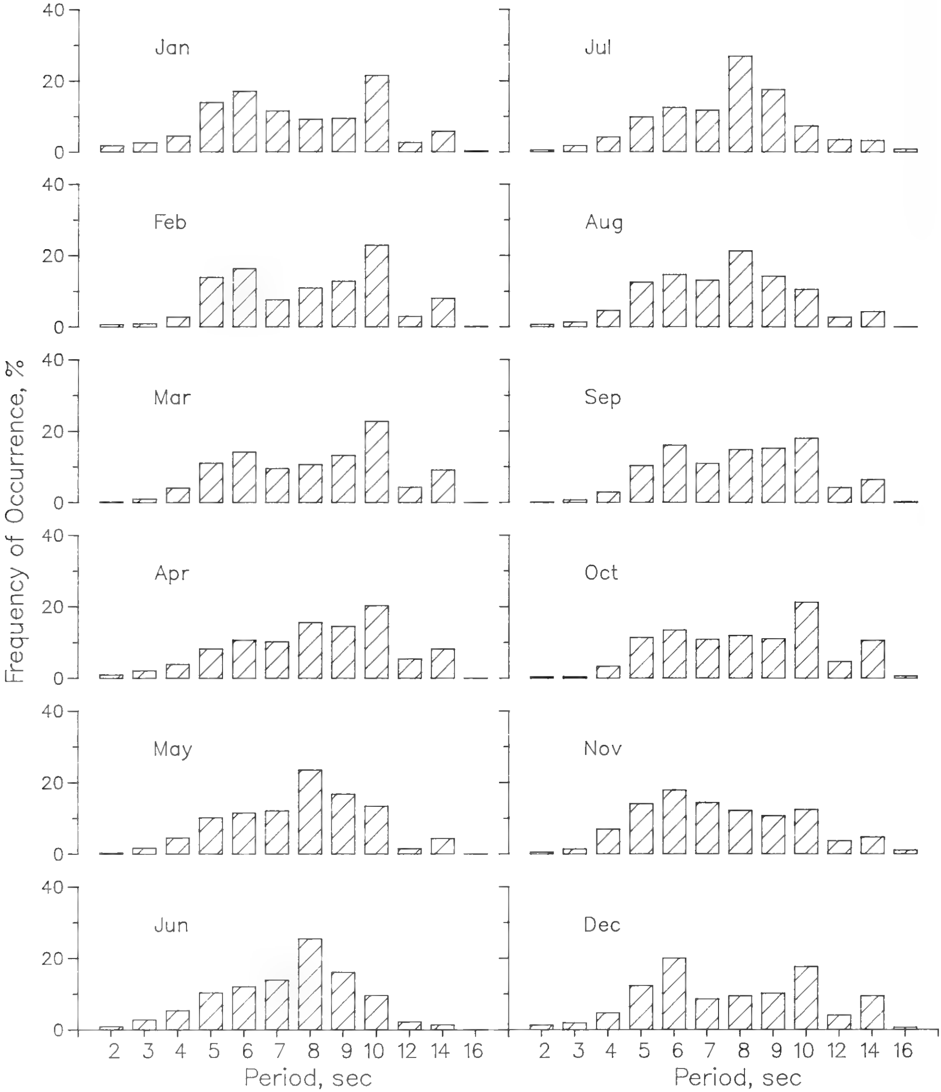


Figure B7. 1980-1988 monthly wave period distributions for Gage 630

Table B5

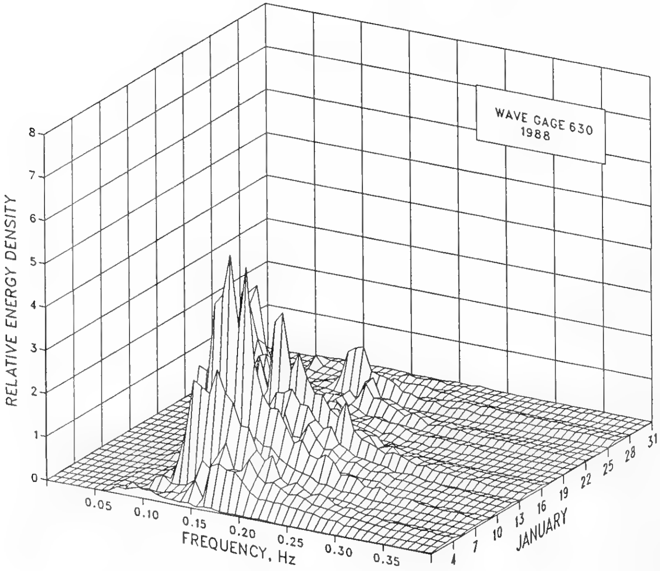
1988 Persistence of H_{mo} for Gage 630

Height (m)	Consecutive Day(s) or Longer																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.5		15	13		12				10	9		8	7				6		5
1.0	52	41	25	17	12		7	6	4	3	2								1
1.5	44	21	12		3	1													
2.0	20	5	1																
2.5	7	2	1																
3.0	4		1																
3.5	1																		
4.0	1																		

Table B6

1980 through 1988 Persistence of H_{mo} for Gage 630

Height (m)	Consecutive Day(s) or Longer																		
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19+
0.5	21	19	16	15	14	13	12		10		9		8	7		5	4		3
1.0	50	33	25	17	13	10	7	5	4	3	2						1		
1.5	39	21	11	6	4	2		1											
2.0	22	11	4																
2.5	10	5	2																
3.0	6	2																	
3.5	3	1																	
4.0	1																		



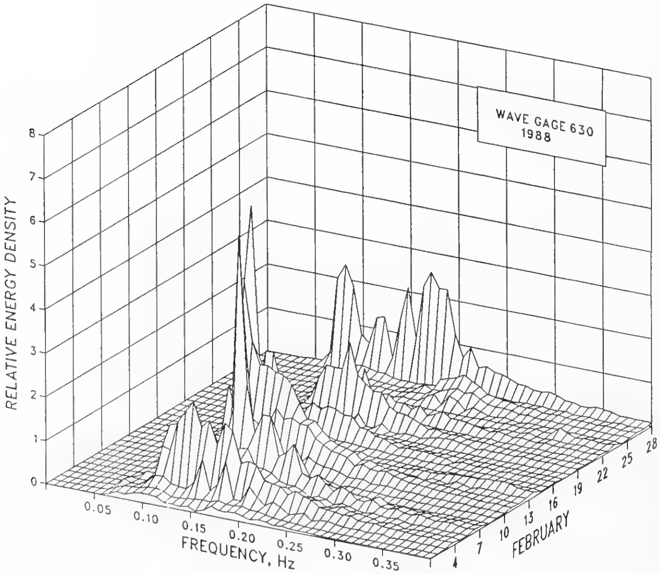
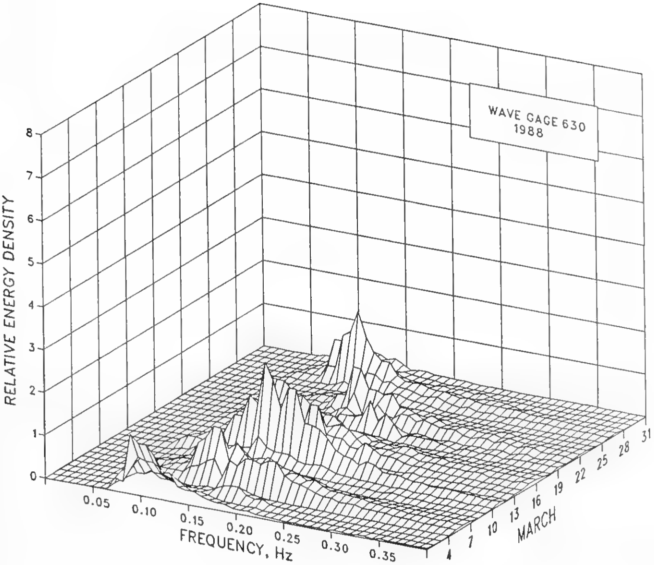


Figure B8. 1988 monthly spectra for Gage 630
(Sheet 1 of 6)



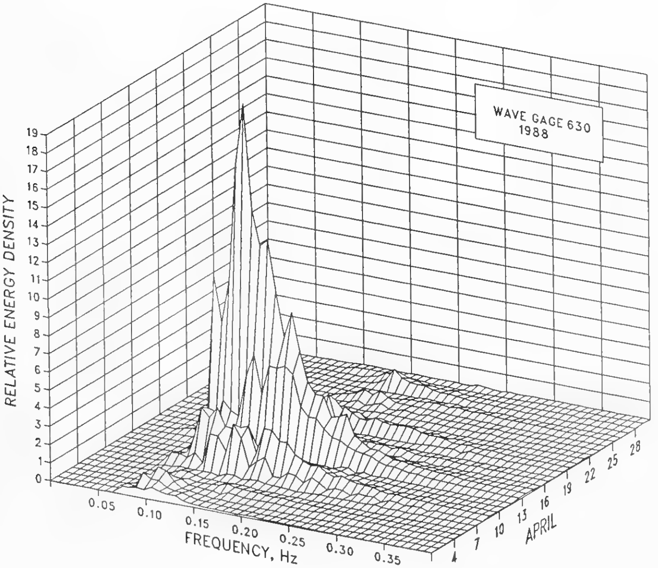
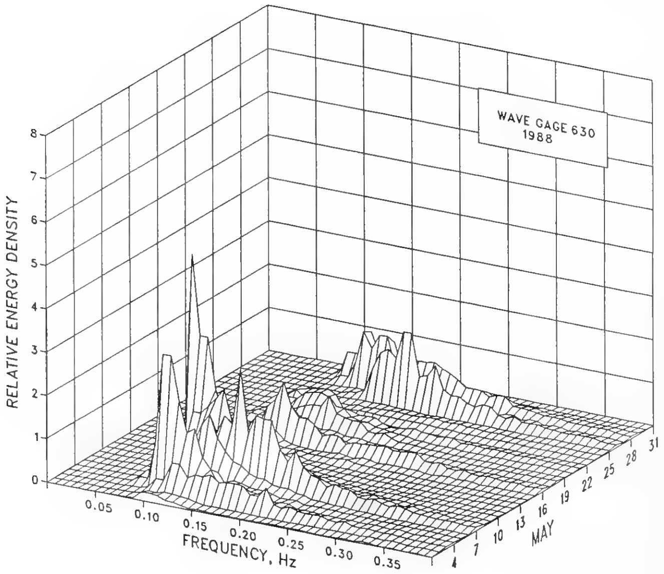
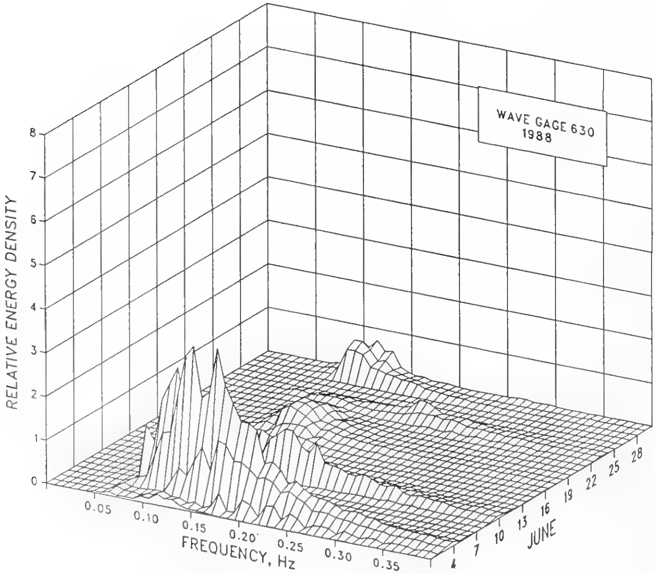


Figure B8. (Sheet 2 of 6)





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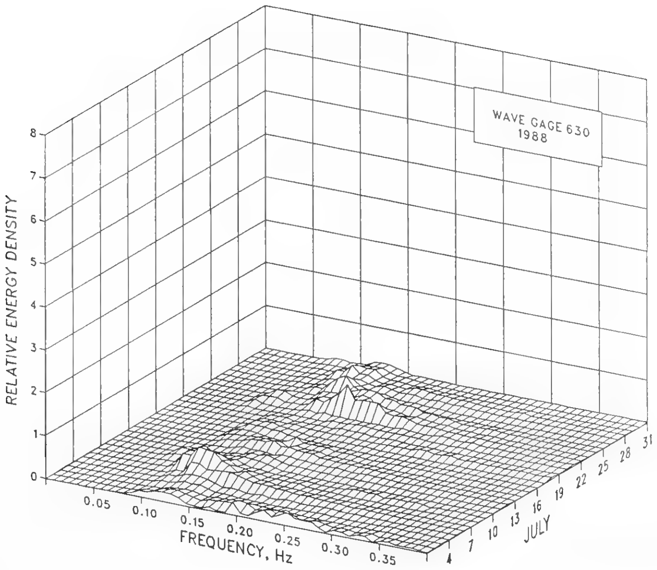


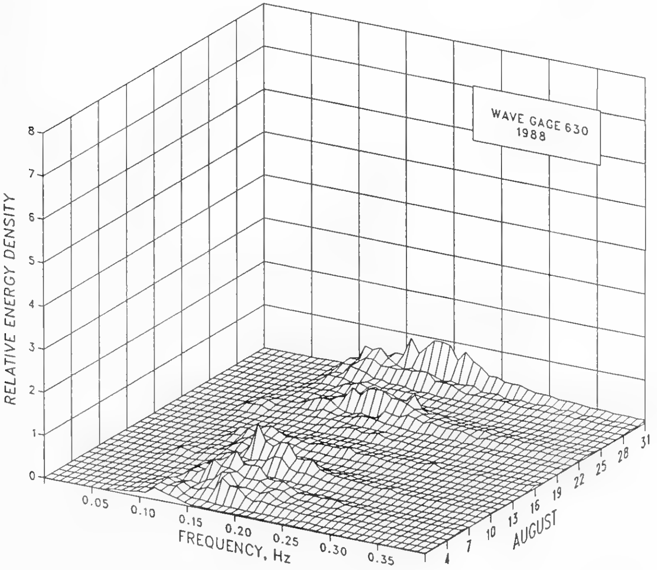
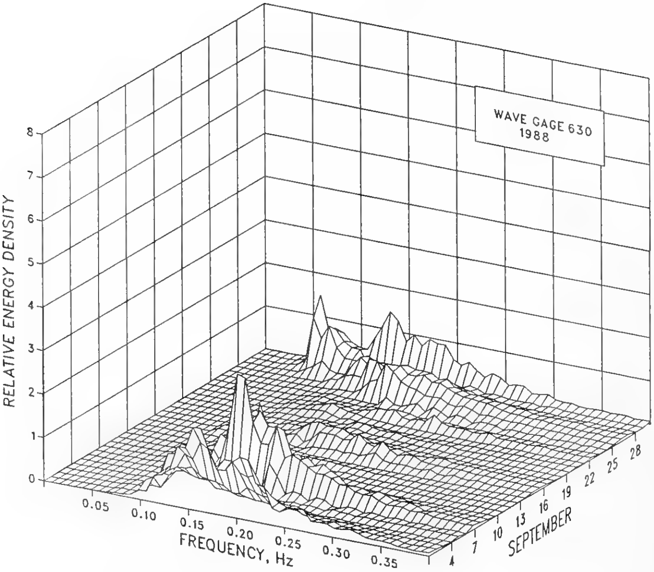


Figure B8. (Sheet 4 of 6)



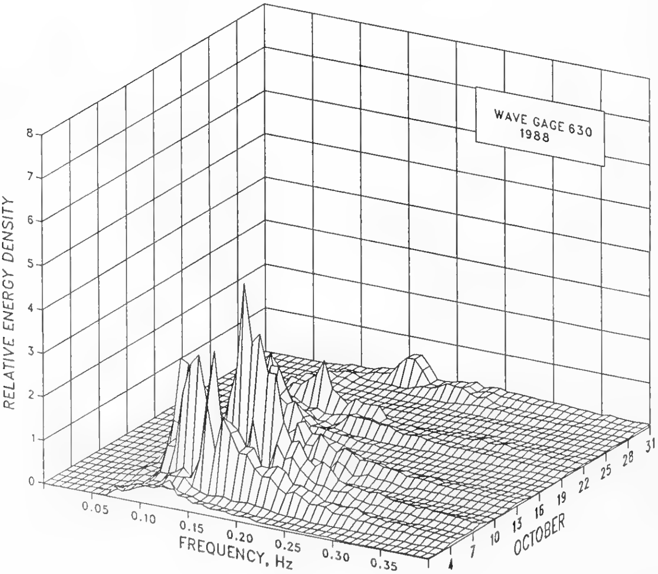
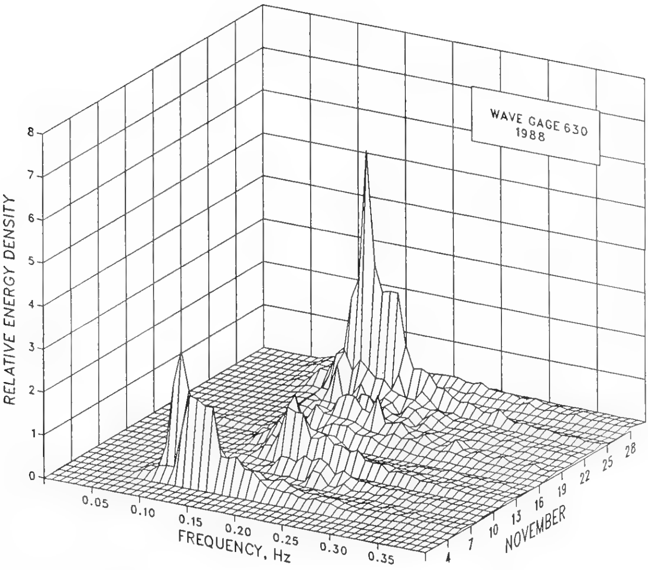


Figure B8. (Sheet 5 of 6)



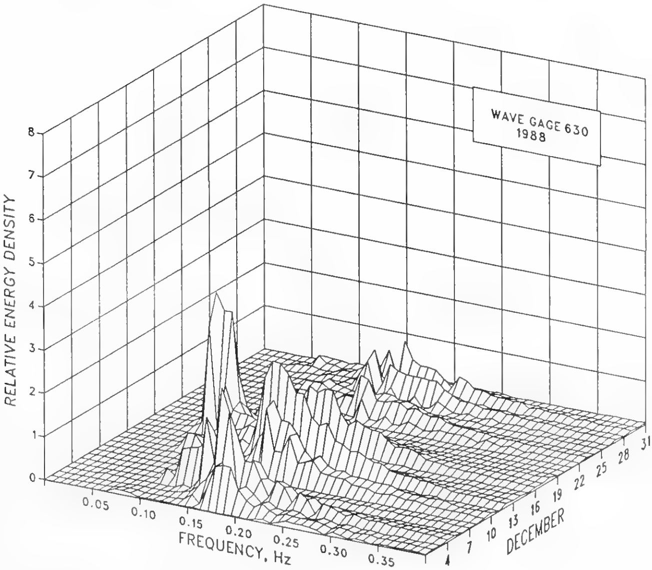
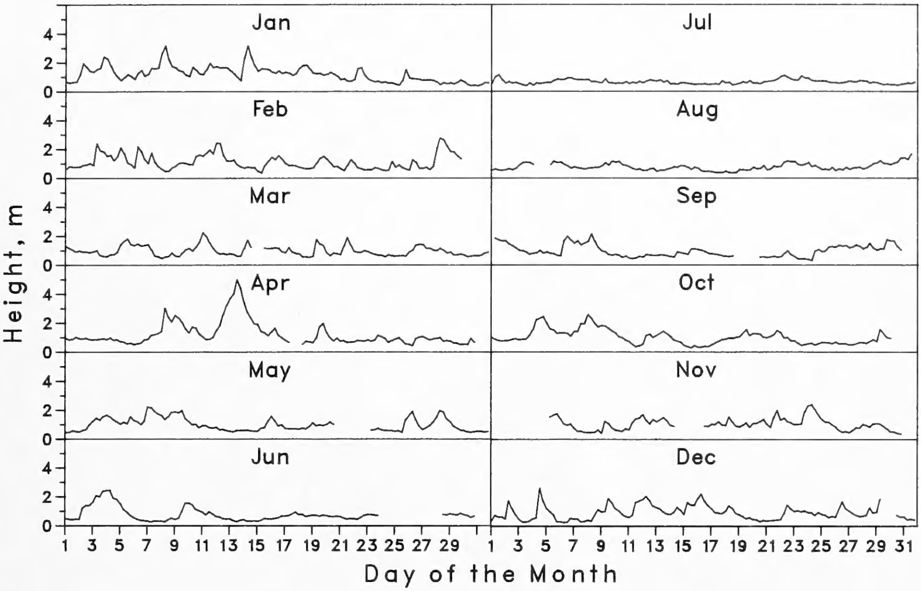


Figure B8. (Sheet 6 of 6)

Table B7

Wave Statistics for Gage 630

	1988							1980-1988						
	Height				Period			Height				Period		
Month	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.	Mean m	Std. Dev. m	Extreme m	Date	Mean sec	Std. Dev. sec	Number Obs.
Jan	1.2	0.6	3.1	8	8.5	3.1	124	1.2	0.7	4.5	1983	8.0	2.8	950
Feb	1.1	0.6	2.7	28	7.8	2.6	116	1.2	0.7	5.1	1987	8.5	2.6	905
Mar	1.0	0.4	2.2	11	7.8	2.2	121	1.2	0.7	4.7	1983	8.6	2.7	998
Apr	1.3	0.9	5.2	13	8.9	3.1	116	1.1	0.7	5.2	1988	8.7	2.8	975
May	1.0	0.5	2.2	7	8.6	1.6	111	0.9	0.5	3.3	1986	8.1	2.3	983
Jun	0.8	0.5	2.4	4	8.0	2.0	101	0.8	0.4	2.4	1988	7.7	2.2	927
Jul	0.7	0.2	1.1	1	7.9	1.7	121	0.7	0.3	2.1	1985	8.1	2.5	948
Aug	0.8	0.3	1.6	31	7.4	2.1	119	0.8	0.5	3.6	1981	7.9	2.4	949
Sep	1.0	0.5	2.1	8	7.8	2.5	111	1.0	0.6	6.1	1985	8.5	2.6	960
Oct	1.0	0.5	2.6	8	9.3	2.7	108	1.2	0.7	4.3	1982	8.7	2.8	1039
Nov	1.1	0.5	2.4	24	6.8	2.1	94	1.2	0.7	4.1	1981	7.9	2.8	861
Dec	1.0	0.5	2.6	4	7.6	3.2	118	1.1	0.7	5.6	1980	8.3	3.0	887
Annual	1.0	0.6	5.2	Apr	8.0	2.6	1360	1.0	0.6	6.1	Sep 1985	8.3	2.6	11382



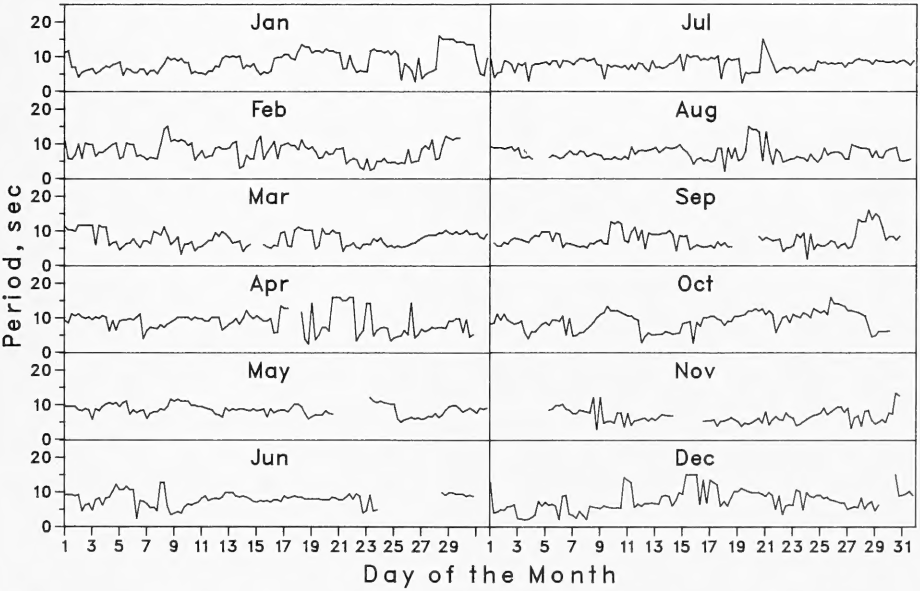


Figure B9. Time-histories of wave height and period for Gage 630